THE UNIVERSITY OF ALBERTA
FACULTY OF ENGINEERING

FURTHER INVESTIGATIONS OF THE EFFECTS OF LIGNOSOL AND CERTAIN OTHER ADMIXTURES IN PREVENTING ICE SEGREGATION IN FREEZING SOILS

by

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INTRODUCTION

The heaving of soils is the result of two distinct phenomena. Heaving due to the expansion of interstitial water on freezing varies from about 1/4" to 1/2" per foot of frost penetration, depending upon the moisture content of the soil and its degree of saturation. This cannot be controlled. The other factor is the formation of ice crystals, usually referred to as ice segregation. It is this factor to which most of the heaving is attributed. But it is this factor also which has been found to have a character such that it can be controlled. To control the heaving, the original hypothesis was that a wetting agent would curb the ice segregation by changing some properties of the soil. Lignosol, being a waste product of the pulp and paper industry and therefore as inexpensive as any other wetting agent, was selected for study.

Laboratory tests were conducted by Hemstock and Sinclair to find the effects of Lignosol on frost heaving. Their conclusion was that it did deter the ice segregation.

In 1947, they showed that 3% to 5% Lignosol, by weight of dry soil, prevented Ice segregation in freezing soils. A field program was initiated shortly after to assess the method for field conditions. The three objectives of the field program were: (1) To ascertain the relative cost of using Lignosol, as compared to continuous maintenance; (2) To reveal the permanency of the treatment; (3) To develop an injection procedure.

Certain heaving sections of the C.N.R. line west of Edmonton were treated, resulting in the reduction of heaving of the railroad subgrade. Periodic levels of the treated sections were taken from 1950 to 1953. From the readings, the permanency of the treatment was ascertained in 1952-53.

In 1953, in an attempt to show that the prevention of heaving was

due to the wetting action of Lignosol, Yurkiw revealed that Aerosol, a superior wetting agent, actually had an effect of promoting heaving and to an extent greater than that incurred by untreated samples. This product is a commercial insecticide having a trade name of Aer-a-sol.

The present program was undertaken to investigate the relationship of the viscosity of the solution admixture with the heaving of soils.

THEORY

In order that there may be ice segregation, certain conditions must be present, the absence of one of which will prevent the action. These conditions are:

(1) Capillary saturation of the soil at the beginninf og, or during, the freezing process.

(2) A free supply of water from within or without the soil.

(3) A minimum percentage (3 to 10 per cent) of grains smaller than 0.02 mm. in diameter.

(4) Freezing temperatures of the air above the soil.

Since Lignosol does reduce frost heaving with all the above-mentioned factors present, its action must be one which modifies one of the conditions to the point where it is practically ineffective as a contributing factor.

For heaving to occur, there must be a rate of flow of water enough that ice lenses may be formed and progressively increase in size. If a clay soil is subjected to heaving conditions, it does not heave appreciably more than the amount directly attributable to the expansion of the water in the soil, on freezing. This is due to the fact that although the clay is fine enough to draw water to the zone of freezing from some depth, the soil voids are too small to permit a rate of flow necessary to form large enough ice crystals within the period of freezing, to incur any appreciable displacement of the surface. In other words, the rate of flow is proportional to the permeability of the soil.

If a soil is saturated with a solution other than water which is thicker (more viscous) than water, then it is the rate of flow of this solution through the soil which governs the flow of water. By continuity, a

greater volume of fluid cannot enter any saturated element of soil than the volume of fluid that leaves it if the fluid is incompressible.

Then if this saturating fluid is more viscous than the water, from Darcy's law it is evident that in effect, the permeability of the soil must change.

Darcy's Law:

$$v = ki \qquad \text{.......} (1)$$

where v is the discharge velocity of the percolating fluid

k is the coefficient of permeability with units of velocity

i is the hydraulic gradient (unitless)

$$k = \frac{K}{\mu} \gamma_w \qquad \text{.......} (2)$$

where K is called the permeability

μ (mu) is the dynamic viscosity in poises

γ_w is the specific weight of water in lb./ft.^{3}

Therefore $v = (\frac{K}{\mu}) \gamma_w i$

$$= \frac{K g i}{\mu} \rho$$

$$= \frac{K g i}{\mu / \rho}$$

$$= \frac{k i g}{\nu}$$

Therefore the velocities of two fluids (1) and (2) will be inversely proportional to the kinematic viscosity ν (nu), i.e. $v_1/v_2 = \nu_2/\nu_1$

Since the heaving of soils is a direct function of the rate of passage of water through the soil, then it is also a direct function of the viscosity of the saturating fluid, if no chemical effects enter the action. With all other contributing factors constant then,

$$\text{Heave} \propto 1/\text{Viscosity}$$

The reduction of heaving by the use of Lignosol originally led to the assumption that the action was due to the wetting characteristics of the admixture. In an attempt to confirm this argument, an unknown type of Aerosol (being another wetting agent) was tested for its effect on heaving. The result was that of the two treated samples, one actually heaved about fifty per cent more than an identical untreated sample, and the other heaved about the same amount as the untreated sample. Therefore some other property of Lignosol was considered to be the controlling factor in the reduction of heaving. Four types of Aerosol, each having its own industrial use, were tested in freezing tests. The heaves were related to the solution viscosities.

Sodium carbonate was used as an admixture for a reason other than the viscosity of the solution. If a soil is a calcium soil, the calcium ion, divalent, binds the clay particles close together, which results in a more open and granular structure. Addition of sodium carbonate will result in the removal of the calcium ions surrounding the soil particles, in the form of a calcium carbonate precipitate. The sodium ions will replace the calcium ions surrounding the soil particles. Soil particles surrounded in this way repel one another, causing a dispersing action which in turn reduces the permeability of the soil. A reduction of permeability would, of course, retard the formation of ice lenses.

A. LABORATORY INVESTIGATIONS

1. Admixtures

Several commercial products were investigated in the laboratory and are herein referred to by their trade names.

Lignosol: Formerly called a waste product of the pulp and paper industry, but should now be referred to as a by-product of the industry because of the many uses which have been found for it industrially.

There are various types of Lignosol, two of which were tested in this program:

Lignosol BD - Calcium lignosulphonate

(B: Calcium

D: May be purchased in powder or liquid form)

Lignosol XD - Sodium lignosulphonate

(X: Sodium

D: May be purchased in powder or liquid form)

All lignosol powders are light brown in color, form dark brown solutions and are soluble in water.

Calgon: A wetting agent used as a water softener.

Aerosol: "Aerosol" is the trade name of a group of wetting agents.

> Wetting agents are substances which are added to surface coatings, water, or oils to increase spreading and penetrating action, to dye solutions to aid penetration, and to adhesives to improve contact. All of these actions result from a more intimate contact of materials at the interface.[1]

Four types of Aerosol were used: OTB, MA, No. 22 and TEF 16. Since the chemical composition of these products will not enter the scope of this

paper, a reference only will be made to the literature concerning it .[1]

Sugar Beet Molasses: A waste product of the sugar-beet industry. It has a slight dispersing action on certain materials (cement), whereas on others it has a strong coagulating effect (titanium oxide).

Sodium Carbonate: Used as a soil dispersant.

2. Viscosity Determinations

Viscosity may be defined as the resistance experienced by one portion of a liquid moving over another portion. The dynamic unit of viscosity is the poise. It is the viscosity of a hypothetical fluid wherein a force of one dyne will cause two parallel liquid surfaces, one centimeter apart, to slide past one another with a velocity of one centimeter per second.

The viscosity of a liquid is generally measured by observing the time required for a definite volume of liquid to flow through a capillary tube under a known pressure difference. The law governing the flow of liquids through a capillary tube was discovered by Poiseuille. He found that the volume of liquid which passed through a capillary tube in a unit time was (1) proportional to the pressure, P, (2) proportional to the fourth power of the radius, R, and (3) inversely proportional to the length of a capillary tube. In symbols, if Q is the volume discharged in unit time,

$$Q = C(PR^4/L)\ldots\ldots\ldots\ldots\ldots\ldots(1)$$

where C is a constant, characteristic for each liquid. Poiseuille did not deduce coefficients of viscosity, but this was done by several physicists who treated the problem mathematically. The equation thus obtained was called Poiseuille's formula:

$$Q = \pi PR^4/8nL\ldots\ldots\ldots\ldots\ldots\ldots(2)$$

where n is the coefficient of viscosity.

An instrument for measuring viscosities is called a viscometer or viscosimeter, and is in effect a U-tube, one arm of which is a capillary tube and the other arm a collecting reservoir for the fluid.

As the same volume of liquid is always used, the height of the column of liquid is always the same, so that the pressures producing the flow are directly proportional to the densities of the fluids. Therefore, if the efflux time for a liquid of known viscosity (n_1) and density (ρ_1) is obtained, then the viscosity of any other liquid may be found by substituting the efflux time (t_2) and the density (ρ_2) of this other fluid into the equation

$$n_2 = n_1 \,(t_2\, \rho_2 / t_1\, \rho_1) \text{ .... } (3)$$

This yields a value for the dynamic viscosity in poises which has units of lb.-sec./ft.^{2}. Another unit of viscosity is the stoke, which is the kinematic unit and is related to the poise by 1 stoke = 1 poise/ρ

Where ρ is the density of the fluid and equals γ/g, in which γ is the specific weight and g is the acceleration due to gravity.

Rearranging equation (3)

$$\frac{n_2}{\rho_2} = \frac{n_1 t_2}{\rho_1 t_1}$$

and since $n/\rho = \nu$,

$$\nu_2 = \nu_1\, t_2/t_1$$

If we let $C = \nu_1/t_1$, then the expression becomes

$$\nu_2 = C t_2 \text{ .... } (4)$$

From equation (4), then, the only value necessary to determine the kinematic viscosity of a fluid, having previously determined C, is the time of efflux.

3. Test Procedure (Viscosity)

Modified Ostwald-type viscometers (Fig. 1) were used to determine the relationship between solution strength and viscosity. The solution strength is expressed by

(Wt. of Lignosol / Wt. of Water) x 100 %

Therefore, fifty grams of Lignosol dissolved in fifty grams of water has a solution strength of 100%.

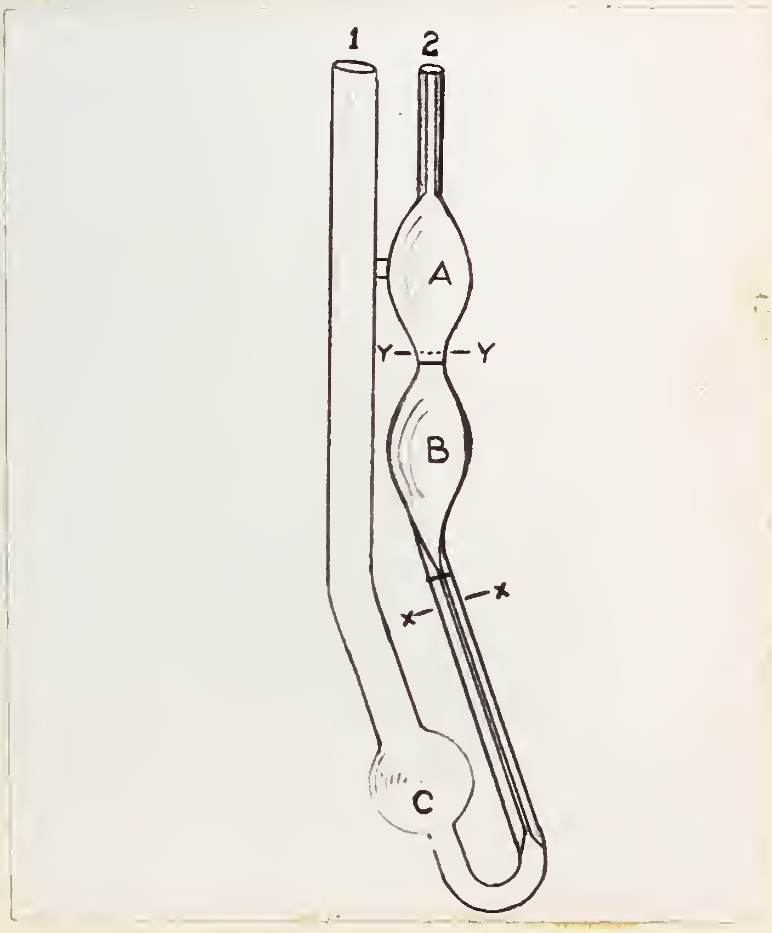

Fig. 1. Modified Ostwald-type Viscosimeter.

Since the freezing of soils is at, or very close to, zero degrees centigrade, the temperature of the solutions was brought to zero degrees centigrade. Samples of 5, 10, 15, 20, 25, 30, 40, 50, 60 and 70% solution strengths were prepared, using 200 grams of distilled water. These were shaken and allowed to stand overnight, to ensure that the Lignosol was fully dissolved.

The viscometer was "loaded" by immersing the small-bore tube into the solution and sucking through the other end until the solution reached the top of the capillary tube. The solution was then allowed to drain out of the tube until it came to X-X, a marking on the tube, by holding a paper towel over the end and letting the towel draw the solution out gradually. The tube was righted (as in Fig. 1), and immersed in an ice-water bath (Fig. 2) at zero degrees centigrade. The temperature control was within 0.1°C. The solution was allowed to run through the capillary tube into Bowl C to cool it before the first trial. A rubber tube was attached to Tube 2, and the solution was sucked up to fill Bulb A partially, after which it was allowed to drain freely downward through the capillary tube. The time taken by the solution to flow from Y-Y to X-X was recorded on a stop-watch marked to 0.2 secs. and read to 0.1 secs.

Usually the first and second trials were erratic, due to insufficient cooling of the solution. At least six trials in close agreement were considered necessary to yield a mean discharge time. Close agreement was considered to be within 0.4 secs.

A series of ten to fifteen trials was made with distilled water, to calibrate the viscometers.

Then from equation (4) $n_{sol'n} = 1.79 \; (t_{sol'n} / t_{water})$

where 1.79 is the kinematic viscosity of distilled water at 0°C. measured in Centistokes.

The water bath was kept at 0°C. by the continuous exchange of the heat energy taken from the water to melt the ice. When this process was too slow to keep the water at 0°C., a little (small handful) common table salt was poured over the ice. This, of course, could cause the temperature to go below zero, as the bath was no longer water, but a salt-water solution. The speed of the paddle, rheostatically controlled, was used to regulate the temperature; the faster it turned, the cooler the bath.

Fig. 2. Apparatus Set-Up for Viscosity Determination at 0°C.

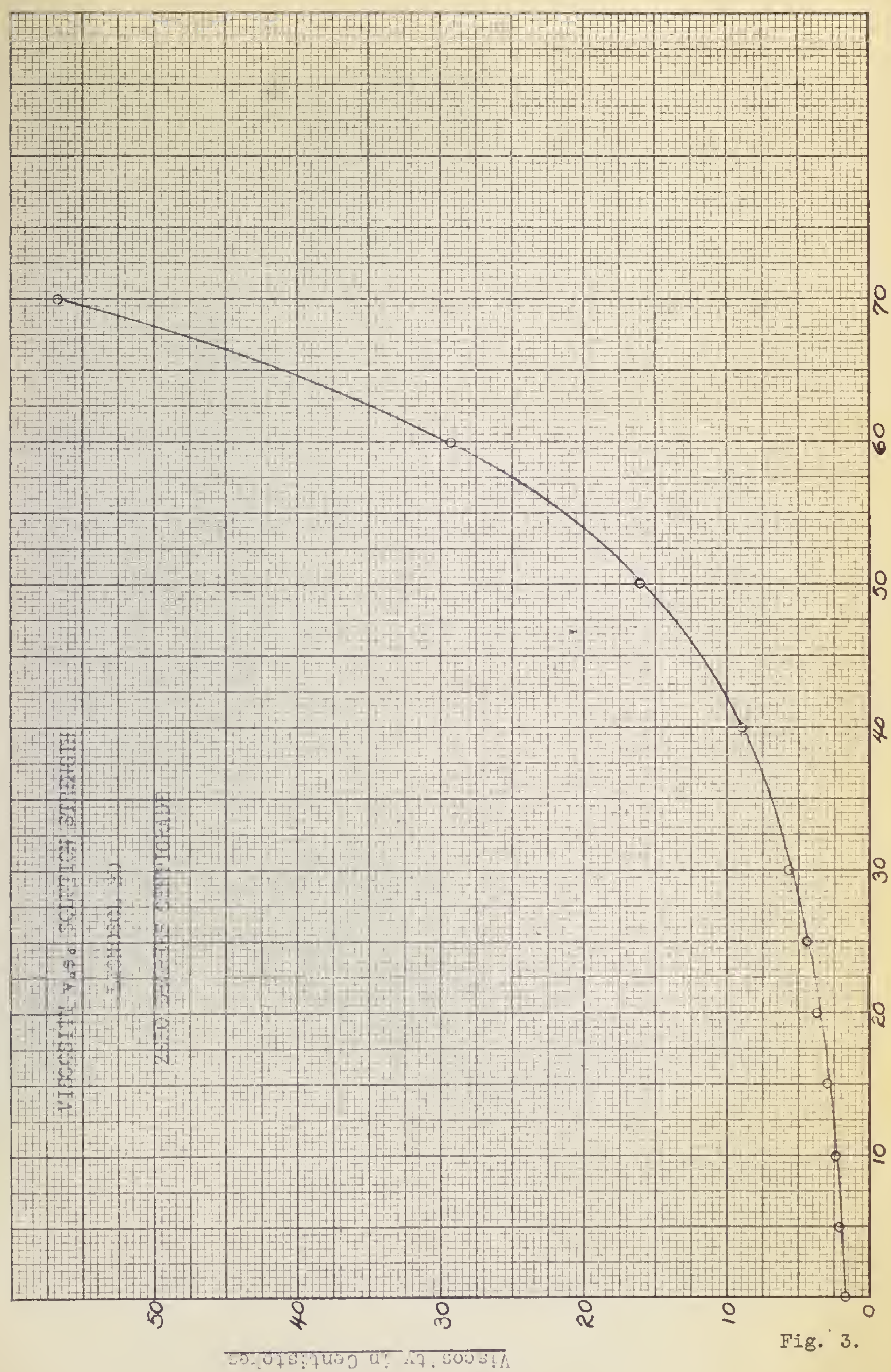
VISCOSITY vs. SOLUTION STRENGTH
ZERO DEGREES CENTIGRADE
70
60
50
40
30
20
10
0
50
40
30
20
10
0
Viscosity in Centistokes

Fig. 3.

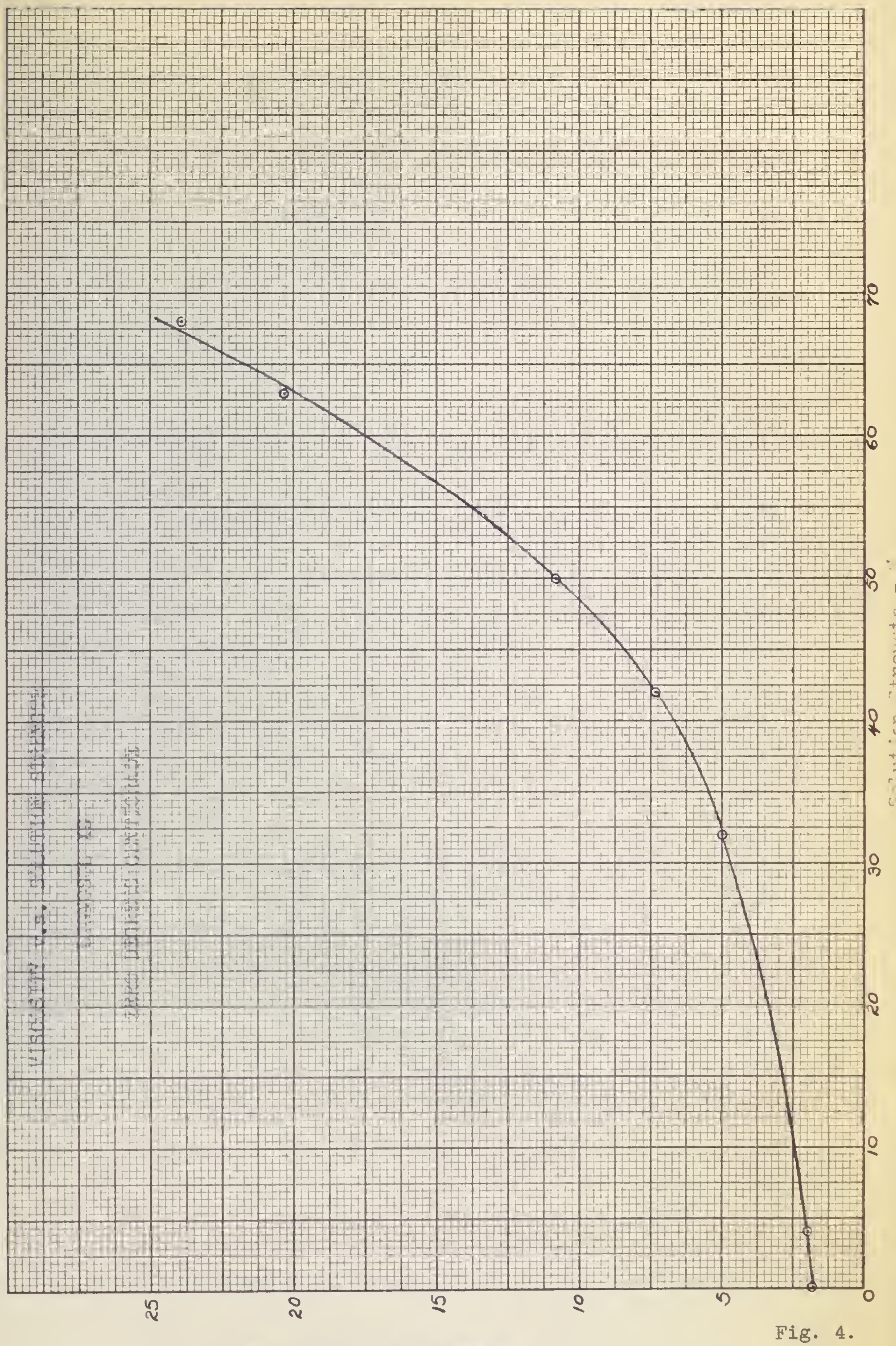

Fig. 4.

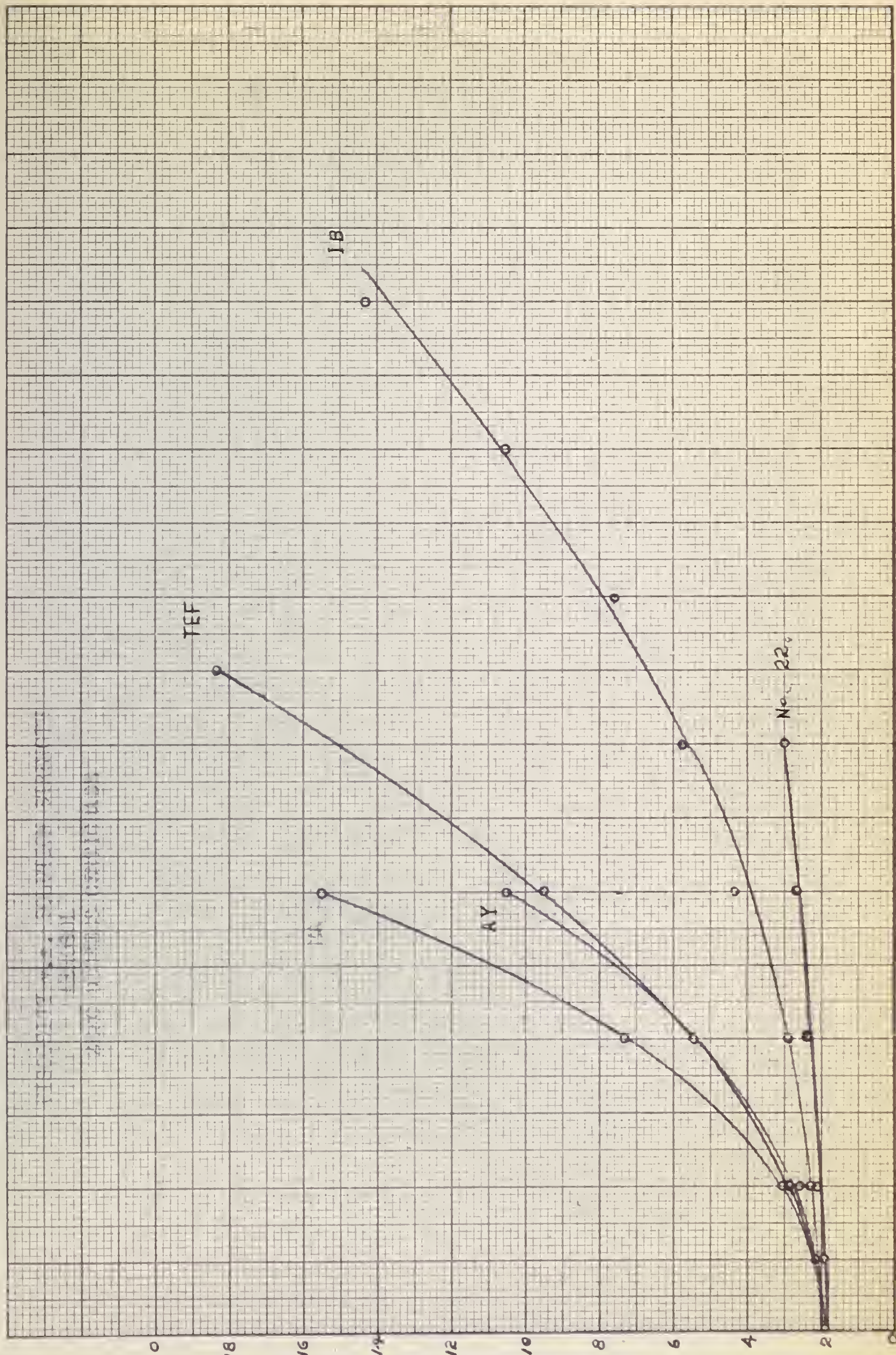

Fig. 5.

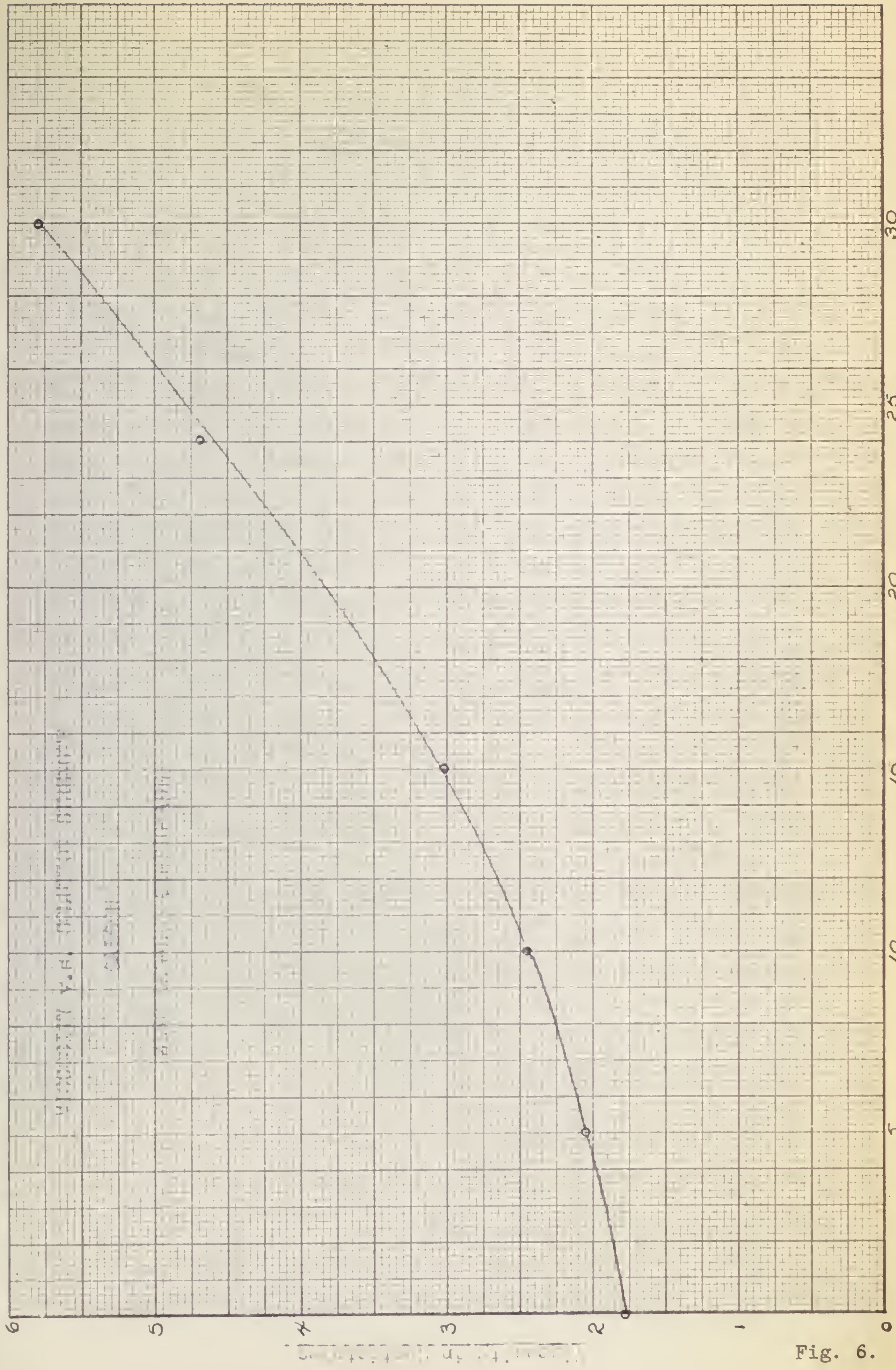

Fig. 6.

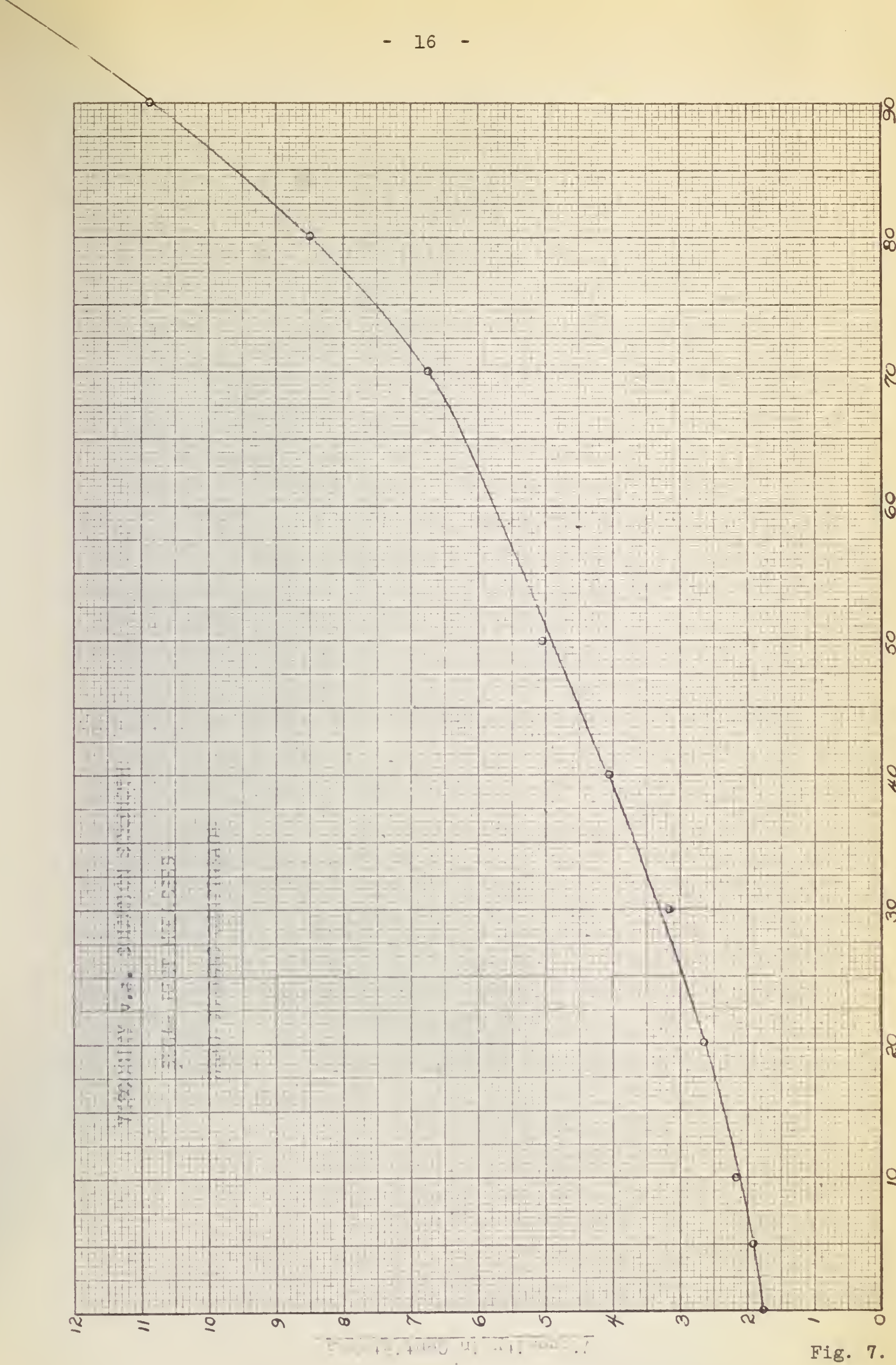

Fig. 7.

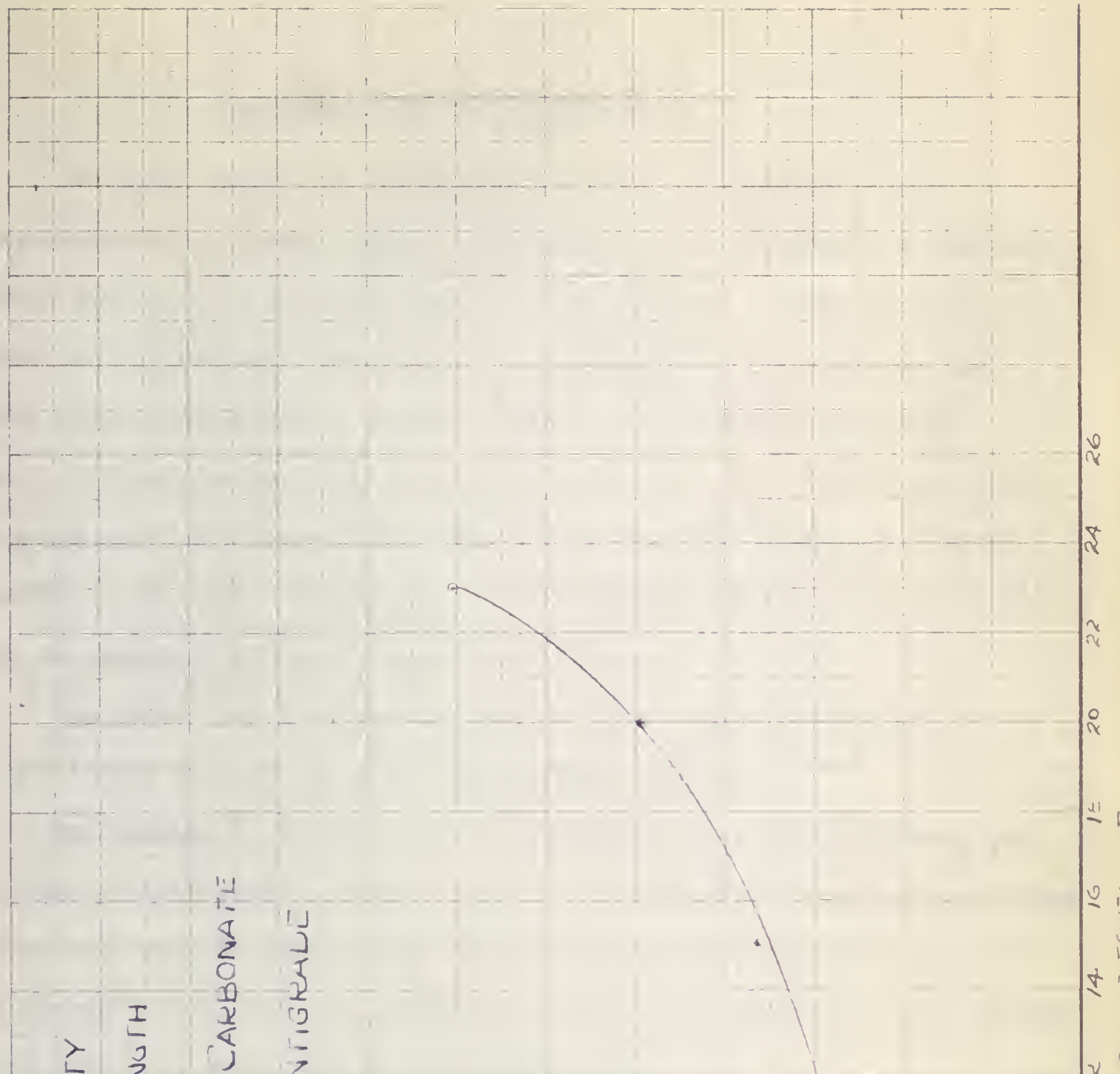
KINEMATIC VISCOSITY
V.S.
SOLUTION STRENGTH
FOR
ANHYDROUS SODIUM CARBONATE
AT
ZERO DEGREES CENTIGRADE
SOLUTION STRENGTH
KINEMATIC VISCOSITY

Fig. 8.

4. Soils Used for Heaving Tests

The soils chosen for the freezing tests were intended to have the characteristics of a material highly susceptible to ice segregation. Samples 1 - 6 were made up of a fine-silt and fine-sand mixture. Although heaves up to 20% of the original specimen height were achieved, it was expected that with more sand in the mixture, greater heaves could have been developed. Samples 7 - 12 were of the same constituents as 1 - 6, but in the proportions of 150 grams sand to 65 grams silt, compared to 140 grams sand and 70 grams silt as for 1 - 6. This new mixture was not sufficiently susceptible for the studies, so another soil was introduced to the tests.

The grain size distribution curves for all samples are shown on Figure No. 9 for each of the soils and for the mixtures.

The samples of soil No. 5 were impregnated by electro-osmosis, and were tested in the freezing cabinet to see if the admixture would still display its heave-reducing characteristics. Electro-osmosis is a method of forcing liquids through soils by direct electrical current, and might be a more feasible method of injection than pumping, in certain cases.

5. Experimental Procedure

Preparation of Test Specimens

Mixing: The soil to be used was air dried and pulverized to break down any lumps. A sample of 250 grams was weighed and placed in a container, and the admixture added. The soil was thoroughly mixed by hand, eliminating all lumps. The jar was sealed and set in the moist room for 24 hours to ensure a complete and even dispersion of the admixture. This procedure was carried out for all the specimens to be tested.

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SOIL MECHANICS LABORATORY

GRAIN SIZE CURVE

PROJECT	
SITE	
SAMPLE	
LOCATION	
HOLE	DEPTH
TECHNICIAN	DATE

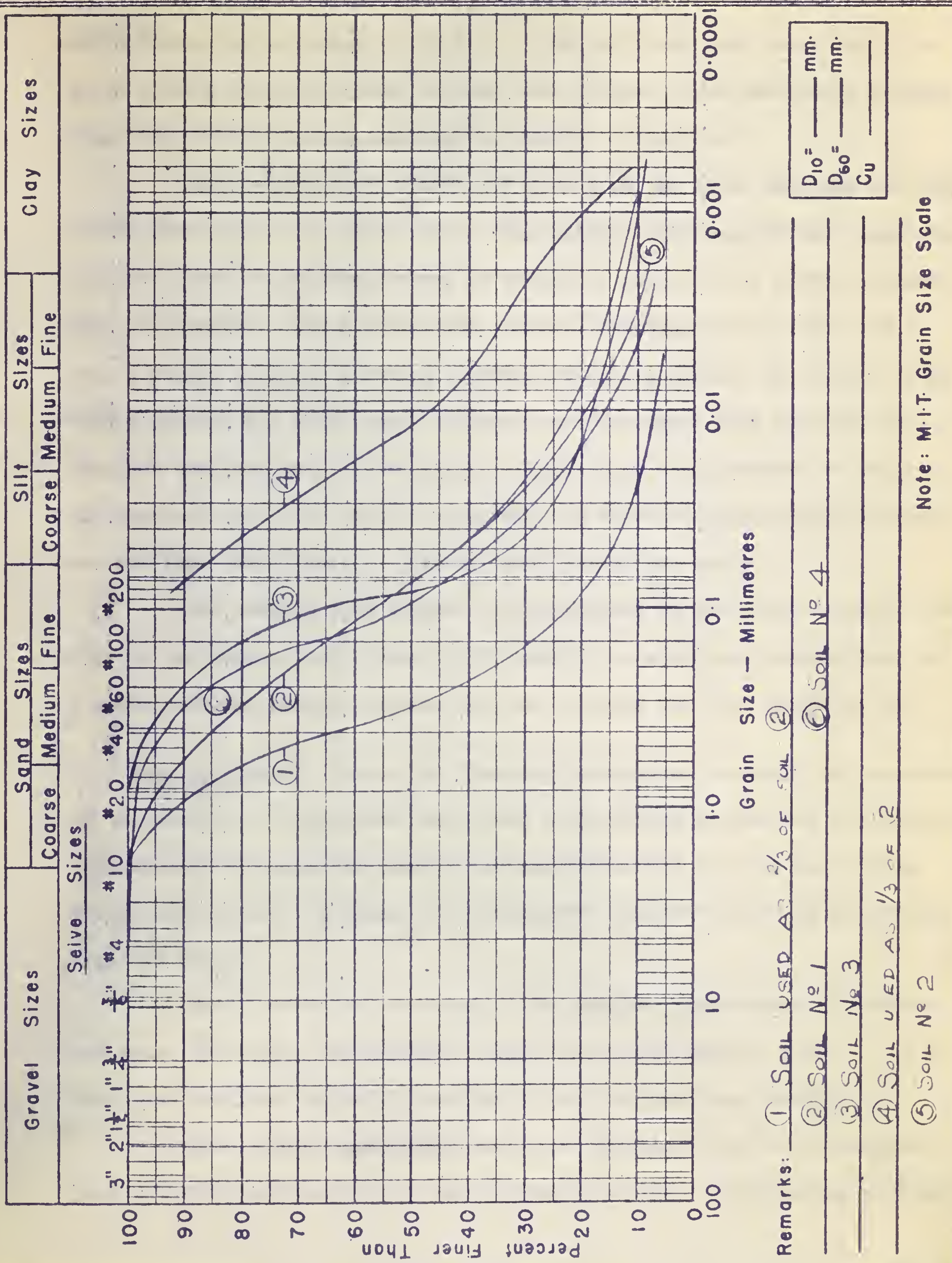


Fig. 9.

<u>Molding</u>: The molding apparatus consisted of a brass tube into which twelve lucite rings, 1.25" I.D., 1.50" O.D. and 0.5" deep, would fit quite loosely but snug enough to keep them aligned. The tube had a cutting edge with which to obtain undisturbed samples if desired.

The twelve lucite rings were placed in the brass tube and the tube placed vertically on a glass plate. The treated soil samples were compacted in five layers, being hand tamped 25 times per layer with a wooden cylinder 3/4" in diameter. The specimen was removed by slipping the brass tube up over a wooden cylinder 1.25" in diameter which was holding the lucite rings firmly against the glass base. Extreme care was taken when handling the specimen confined only by the rings. These rings were intended to confine the specimen laterally, but to eliminate any adhesive effects when the soil was heaving. Such adhesive effects would reduce the heave.

The samples were weighed and introduced to the frost cabinet. The tops of the samples were coated with paraffin to eliminate evaporation, and a small hole was punched through the wax to allow the free escape of air.

<u>Test Procedure</u>: Before the freezing process was started, the elevations of the tops of the specimens were found with respect to the top of the freezing cabinet, by measuring down to the specimens from a steel bar resting across the cabinet. Readings were considered positive below this datum and negative above.

Daily elevation readings of the samples, temperature of the room and water reservoir, and reservoir water level were taken. Tables I to XI inclusive tabulate the daily readings of all the specimens tested.

Some samples were subjected to an immediate drop in temperature down to -20°C. whereas others were gradually frozen. The freezing procedure

was terminated when the samples showed no further heaving, or showed erratic behavior.

Figs.10 & 11 are photographs of some of the specimens, which more fully describe the character of the samples after heaving.

Throughout the procedure the water supply reservoir was replenished to adhere to the "open system" theory whereby there is a constant supply of water from without (beneath) the soil. The reservoir water was examined for any marked degree of discoloration due to leaching out of the admixture.

The zonolite insulation adjacent to the samples was agitated each day, so that water coming through the soil from below would not be drawn out of the soil at the exposed faces between lucite rings which had parted.

Final moisture contents were determined for each layer from some of the samples, a layer being that thickness of soil bounded by two other visually distinct layers having different characteristics with respect to the state of solidity and moisture content.

6. Frost Action Equipment

To simulate any freezing conditions required, the cold room had a thermostatically-controlled blower-type refrigeration system which was able to regulate the temperature between 10°C. and -30°C. The temperature could be dropped slowly or rapidly, and could be caused to fluctuate if desired. The refrigeration plant used a freon compressor powered by a 1-1/2 H.P. motor.

The Frost Action Cabinet is shown schematically in Fig. 12.

The samples were insulated by coarse zonolite, with their tops exposed to the air. In this way, freezing progressed from the top downward, and the similarity to natural heaving conditions was produced. The reservoir water was

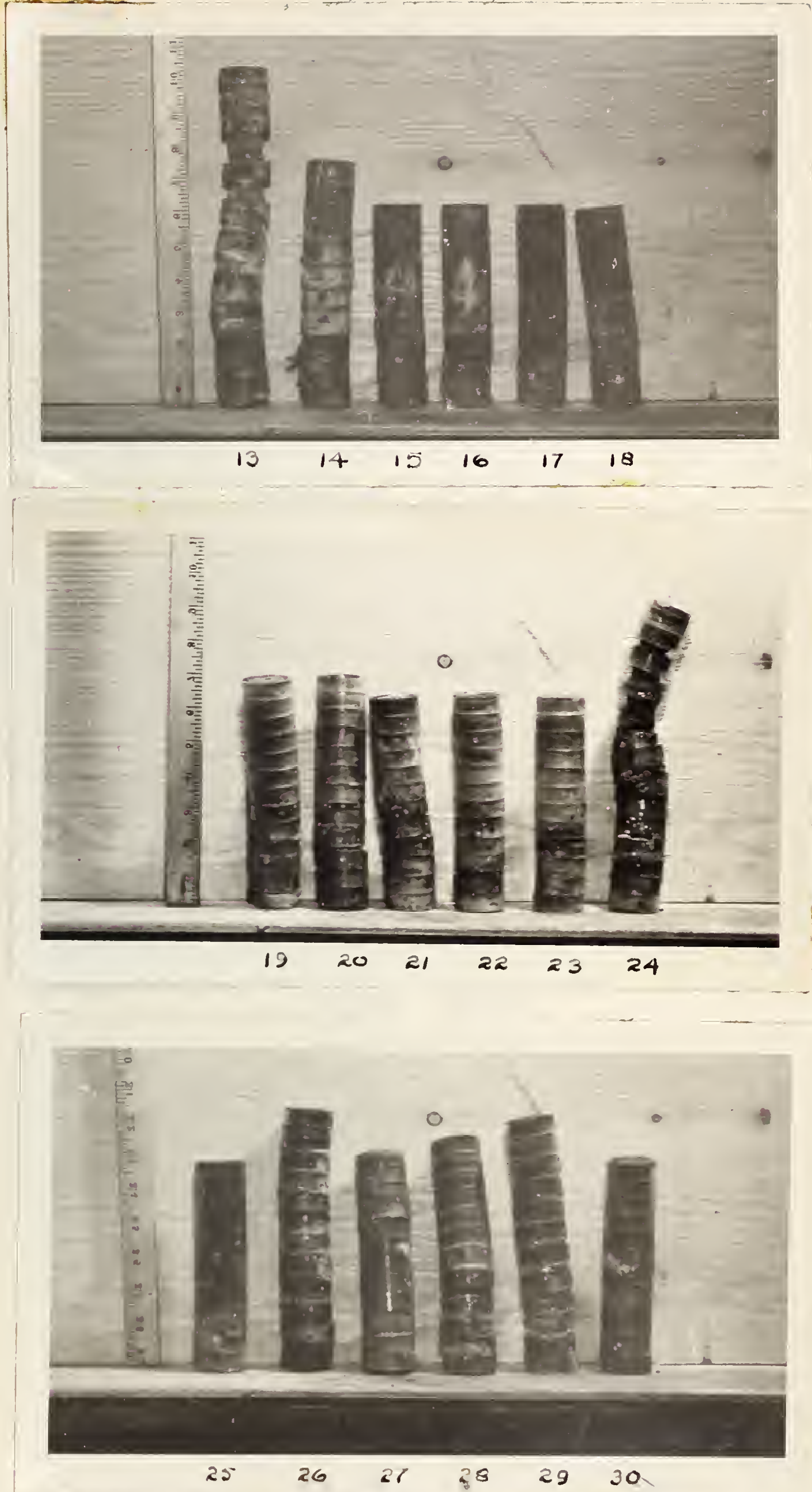


Fig. 10. Heaved Specimens.

37 38 39 40 41 42

47 48 49 50

43 44 45 46 47 48 49 50 51 52 53 54

Fig.11. Heaved Specimens.

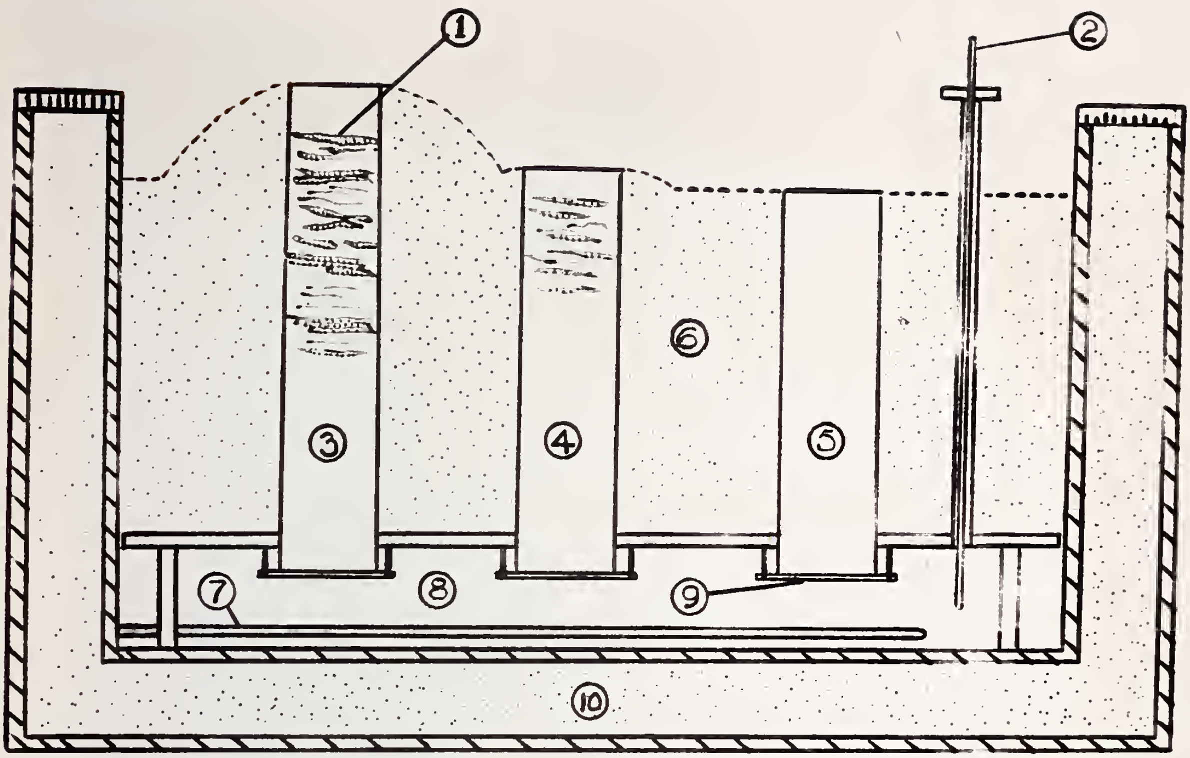


Fig. 12. FROST ACTION CABINET.

1. Ice Lenses.
2. Thermometer.
3. Untreated specimen after some freezing period.
4. Treated specimen after some freezing period.
5. Specimen before any freezing.
6. Zonolite Insulation.
7. Water Heater.
8. Water Reservoir.
9. Porous Bronze Plates.
10. Insulation.

warmed by an immersed rod heater thermostatically set for a range of about 3 to 9°C.

The specimens rested on porous bronze plates about 1/2" below the water level. These plates were attached to the sample-holding board. The board was elevated by four legs which allowed a 2" reservoir depth.

The water was fed to the zone of freezing by capillarity.

There were two Frost Action Cabinets, one of which would hold six samples, and the other, twelve.

7. Discussion of Laboratory Data

General: Tables I to XI are the complete records of the data taken during the freezing tests. The samples indicated on any one table may be compared to one another, but cannot be compared to samples on any other table since different tables are representative of different freezing conditions. Slight variations in freezing conditions, such as room temperature fluctuation, water temperature variation, and variations in the insulating qualities of the zonolite, had very noticeable effects on the heaving of the samples. However, since one of the freezing cabinets held twelve samples, Tables IV & V, and VIII, IX & X may be compared. These tables have all the pertinent data regarding the treatment of the samples.

The data on these tables has been plotted on Figs. 13 to 23. These rate of heave curves present a visual picture to afford a clearer understanding of the heaving process.

Photographs were taken of some of the samples shortly after they were taken from the Frost Action Cabinet, to record permanently the character of the heaving.

TABLE I. SPECIMEN HEAVE DATA FOR SAMPLES 1 TO 6

Elapsed Time in Days	Water Temp. °C	Air Temp. °C	Accum. Degree Hours Freezing	Specimen Nos. 1 Heave	2 Heave	3 Heave	4 Heave	5 Heave	6 Heave
0	+9	0	0	0	0	0	0	0	0
4	+9	-2	192	0	0	0	0	0	0
5	+8	-3	264	0	0	0	0	0	0
7	+8	-3	408	0	0	0	0	0	0
10	+7	-3	624	0	0	0	0	0	0
11	+8	-9	840	0	0.83	0	0	0	1.82
12	+8	-11	1104	0	0.83	0.50	0.67	0	1.82
14	+6	-11	1632	0	0.83	0.50	0.67	4.17	6.00
16	+7	-13	2260	1.67	3.33	2.50	1.50	5.17	6.91
17	+8	-13	2570	2.00	4.17	3.33	2.50	6.00	6.91
18	+8	-13	2880	2.50	4.17	3.33	2.84	5.67	7.08
19	+8	-13	3190	3.00	5.34	4.17	5.67	6.34	8.74
21	+8	-15	3910	3.33	5.50	5.17	6.50	7.00	10.00
23	+8	-14	4582	3.67	6.17	5.84	7.34	8.17	13.10
24	+8	-15	4942	4.17	6.34	6.17	7.34	8.50	13.81
25	+8	-19	5398	4.17	6.34	6.67	7.17	10.18	14.55
26	+8	-19	5854	4.33	6.34	7.34	8.17	11.18	15.10
27	+8	-20	6334	5.00	6.67	7.84	8.17	11.82	15.45
28	+7	-29	7030	5.16	7.00	8.50	8.84	14.32	16.37
30	+6	-31	8518	5.84	7.17	10.00	9.34	15.50	17.81
31	+6	-31	9262	6.17	7.17	10.68	9.34	16.85	18.72
32	+6	-31	10006	6.17	7.17	11.00	9.34	17.69	18.72
34	+6	-31	11494	6.17	7.17	11.67	9.34	19.32	18.72
Initial Moisture Content				5.91	6.34	6.97	8.04	10.39	8.97
Final Moisture Content				40.92	39.94	40.63	35.84	37.40	51.90
Initial Dry Density (#/ft.^{3})				93.1	91.0	90.7	95.7	91.7	91.2
Initial Degree of Saturation				19.8	20.1	21.9	28.5	33.5	28.2
Heave Due to Pore Water Freezing:- Inches.				0.05	0.05	0.06	0.06	0.08	0.07
- %.				0.83	0.83	1.00	1.00	1.33	1.17
Admixture.				Lig. BD	Lig. BD	Lig. BD	Lig. BD	Lig. BD	Lig. BD
Solution Strength (%).				68.0	55.5	42.5	28.0	4.0	0
Kinematic Viscosity (Cstks.) . .				50.0	22.5	10.1	5.0	2.0	1.8
Soil Used.				1	1	1	1	1	1

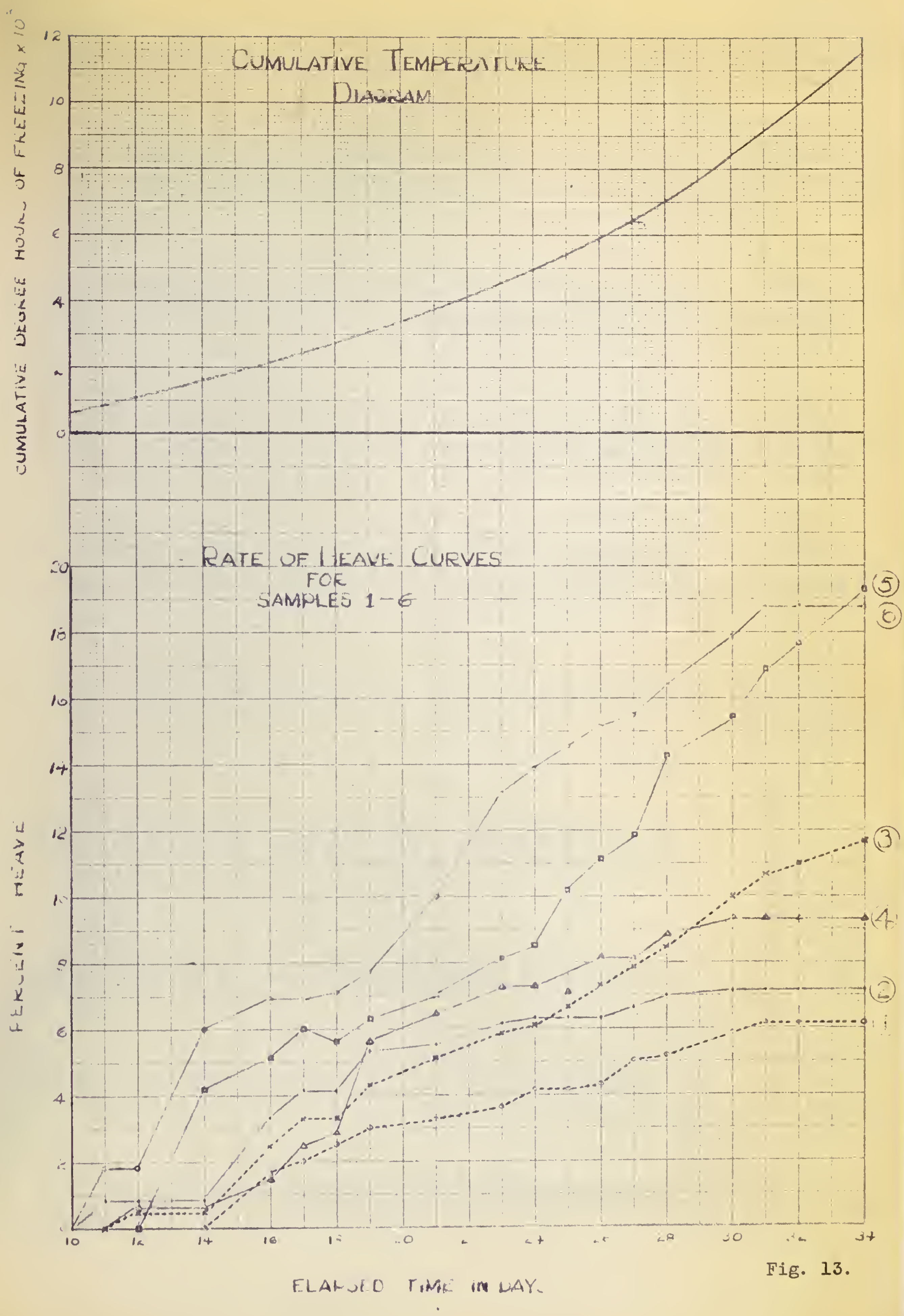

CUMULATIVE TEMPERATURE DIAGRAM
RATE OF HEAVE CURVES FOR SAMPLES 1-6
PERCENT HEAVE
ELAPSED TIME IN DAYS

Fig. 13.

TABLE II. SPECIMEN HEAVE DATA FOR TABLES 7 TO 12

Elapsed Time in Days	Water Temp. °C	Air Temp. °C	Accum. Degree Hours Freezing	Specimen Nos. 7 Heave	8 Heave	9 Heave	10 Heave	11 Heave	12 Heave
0	+8	0	0	0	0	0	0	0	0
1	+8	-23	552	0	0.50	0	0.83	4.17	4.33
2	+8	-31	1296	0.33	1.17	0.10	2.50	7.33	8.34
3	+9	-32	2064	0.83	1.17	1.50	3.50	8.66	10.18
4	+9	-33	2856	1.67	1.33	1.67	3.50	9.16	11.00
6	+7	-33	4440	3.50	2.00	3.83	6.67	11.00	13.68
7	+8	-32	5208	4.50	3.17	4.50	7.67	11.00	13.68
8	+9	-33	6000	4.84	3.83	5.50	8.00	11.50	13.68
9	+9	-34	6816	5.17	4.33	6.00	8.67	11.82	14.00
10	+9	-27	7464	3.84	3.17	4.84	7.50	8.83	11.18
11	+9	-33	8256	5.00	3.67	4.84	9.00	9.00	11.68
12	+9	-33	9048	5.84	5.00	6.00	9.83	9.66	12.33
13	+9	-32	9816	6.67	4.67	6.67	9.83	10.18	12.33
14	+9	-31	10560	6.84	5.34	7.50	10.32	10.33	12.83
15	+9	-31	11304						
16	+9	-31	12048	6.17	5.84	8.00	10.83	8.83	13.68
17	+9	-31	12792	5.50	6.00	8.17	10.83	9.16	15.00
18	+9	-30	13512	5.34	7.17	8.17	10.83	8.83	15.18
19	+9	-30	14232	5.34	7.34	7.84	10.83	9.00	15.83
20	+9	-30	14952	4.67	8.00	6.67	10.18	8.83	13.68
21	+9	-30	15672	4.33	7.50	6.67	9.67	8.66	12.33
22	+9	-30	16392	3.00	5.50	7.34	9.17	8.66	12.00
23	+9	-30	17112	2.50	5.17	8.17	10.00	8.83	12.18
24	+10	-30	17832	2.50	5.17	8.50	10.00	8.83	11.68
25	+8	-30	18572	2.50	4.67	8.84	10.18	8.83	11.68
26	+8	-30	19272	3.84	6.00	10.16	10.83	12.84	11.68
Initial Moisture Content				8.76	10.03	9.80	10.28	13.56	13.60
Final Moisture Content				See Plate No.		for variation in moisture contents.			
Initial Dry Density (#/ft.^{3})				94.2	101.7	100.0	101.5	101.2	94.7
Initial Degree of Saturation				30.1	41.3	38.8	42.1	55.1	47.1
Heave Due to Pore Water Freezing:- Inches.				0.07	0.08	0.08	0.09	0.12	0.11
- %.				1.17	1.33	1.33	1.50	2.00	1.84
Admixture.				Lig. XD	Lig. XD	Lig. XD	Lig. XD	Lig. XD	Lig. XD
Solution Strength (%).				68.0	55.5	42.5	28.0	4.0	0
Kinematic Viscosity (Cstks.) . .				25.0	14.1	7.5	4.4	2.0	1.8
Soil Used.				2	2	2	2	2	2

TABLE II(a). VARIATION OF MOISTURE CONTENT WITH DEPTH

Samples 7 to 12. Rings numbered 1 to 12, top to bottom.

Sample No.:	7	8	9	10	11	12
Admixture:	Lig.XD	Lig.XD	Lig.XD	Lig.XD	Lig.XD	Lig.XD
Sol'n Strength:	68	55.5	42.5	28	4	0
Moisture Content (%):						
Ring No. 1	8.15	10.56	9.75	12.21	15.06	17.19
" 2					17.75	23.00
" 3	12.15		11.92		18.75	22.94
" 4		16.55		19.55	17.50	24.30
" 5	19.21	23.40			16.75	
" 6			26.00	39.12	20.30	28.10
" 7	42.00	51.80			21.40	28.50
8		23.10	39.30		64.0	70.32
9	24.20	23.20		--		
" 10			--		==	--
" 11	--	--	--	--	--	--
" 12	--	--	--	--	--	--

Sample No. 7: No heaving at bottom of No. 6. 1/8" parting between Nos. 6 & 7 and Nos. 8 & 9. 1/4" parting between Nos. 7 & 8. 7 & 8 solid.

Sample No. 8: No heaving down to No. 4. 1/8" parting between Nos. 4 & 5 and Nos. 5 & 6. 1/4" parting between Nos. 6 & 7 and Nos. 7 & 8. 1/8" parting between Nos. 8 & 9 and Nos. 9 & 10.

Sample No. 9: No heaving at all down to bottom of No. 5. Not solid at all. Saturated from No. 5 down. Free water in evidence.

Sample No. 10: Very slight heave down to No. 4. Most between Nos. 5 & 8. Sample not so solid as Samples 11 and 12.

Sample No. 11: Evenly heaved. Frozen to bottom of No. 10. Main ice lense from midway in No. 9 to midway in No. 10. Sample solid throughout.

Sample No. 12: Evenly heaved. Frozen to bottom of No. 9. Main ice lense from midway in No. 8 to midway in No. 9. Sample solid throughout.

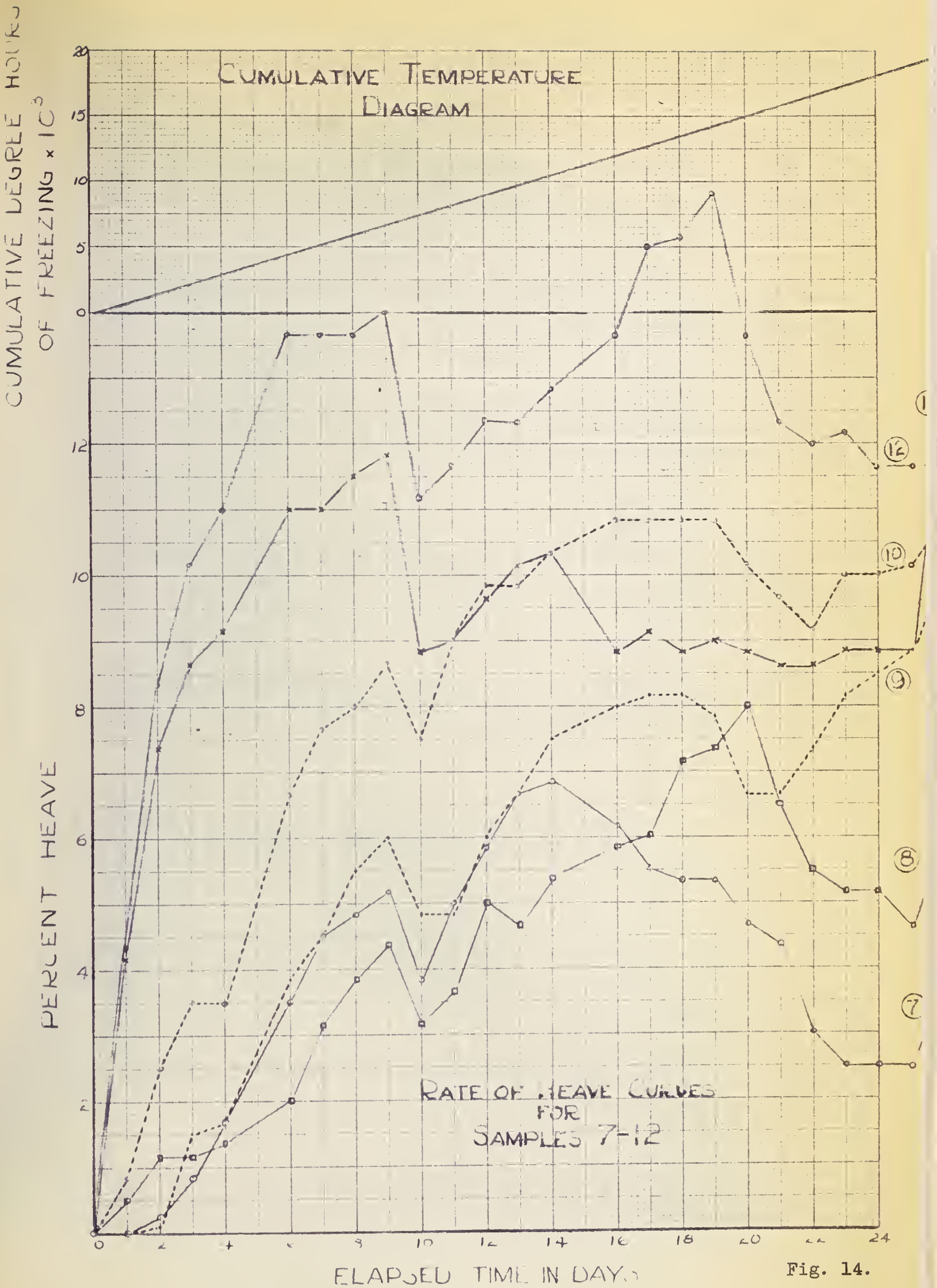

CUMULATIVE TEMPERATURE DIAGRAM
CUMULATIVE DEGREE HOURS OF FREEZING × 10³
PERCENT HEAVE
RATE OF HEAVE CURVES FOR SAMPLES 7-12
ELAPSED TIME IN DAYS
20
15
10
5
0
12
10
8
6
4
2
0
4
8
10
14
16
18
24
12
10
9
8
7

Fig. 14.

TABLE III. SPECIMEN HEAVE DATA FOR SAMPLES 13 TO 18

Elapsed Time in Days	Water Temp. °C	Air Temp. °C	Accum. Degree Hours Freezing	Specimen Nos. 13 Heave	14 Heave	15 Heave	16 Heave	17 Heave	18 Heave
0	+10	0	0	0	0	0	0	0	0
1	+8	-3	72	0	0	0	0	0.50	1.33
2	+8	-6	216	0	0	0	0	2.67	9.00
3	+7	-8	308	0	0	0	0	3.50	14.00
4	+7	-7	476	0	0.17	0	0	4.84	17.17
5	+6	-7	644	0	0.17	0	0	5.50	18.32
6	+7	-8	836	0	0.33	0	0	5.67	20.50
7	+7	-8	1028	0	0.33	0	0	6.00	24.00
8	+7	-9	1244	0.50	0.33	0	0	6.50	28.00
9	+7	-8	1436	0.50	0.33	0	0	6.67	28.80
10	+6	-8	1628	0.50	0.33	0.17	0	8.17	31.30
11	+7	-14	2064	0.50	0.33	0.50	0	10.18	40.50
12	+6	-13	2376	0.50	0.33	0.50	0.50	12.18	43.00
13	+8	-15	2736	0.50	0.33	0.50	0.83	13.18	48.00
14	+7	-15	3096	0.67	0.33	0.67	0.83	14.00	51.40
15	+7	-15	3456	0.83	0.33	0.67	0.83	15.68	54.70
16	+7	-20	3936	1.00	0.33	1.33	0.33	18.18	59.60
17	+7	-22	4464	1.00	0.33	1.50	0.33	19.00	61.30
18	+6	-21	4968	1.00	0.33	1.50	0.50	19.85	62.10
19	+8	-22	5496	1.00	0.33	1.50	0.50	20.20	63.00
20	+8	-28	6168	1.00	0.33	1.83	1.43	21.50	64.00
21	+6	-30	6888	1.00	0.33	2.67	1.43	23.20	64.70
22	+8	-30	7608	1.00	0.33	2.67	1.43	24.00	65.50
Initial Moisture Content				11.54	13.19	14.12	14.41	19.42	20.00
Final Moisture Content				14.32	17.50	17.32	13.80	37.40	62.70
Initial Dry Density.				115.0	116.1	110.2	111.1	104.1	103.5
Initial Degree of Saturation				67.0	78.8	72.6	75.5	87.0	85.9
Heave Due to Pore Water Freezing:- Inches.				0.12	0.13	0.14	0.14	0.17	0.18
- %.				2.00	2.17	2.33	2.33	2.84	3.00
Admixture				Lig. XD	Lig. XD	Lig. XD	Lig. XD	Lig. XD	Lig. XD
Solution Strength (%)				63.0	50.0	42.0	32.0	4.0	0
Kinematic Viscosity				20.0	10.8	7.3	5.0	2.0	1.8
Soil Used				3	3	3	3	3	3

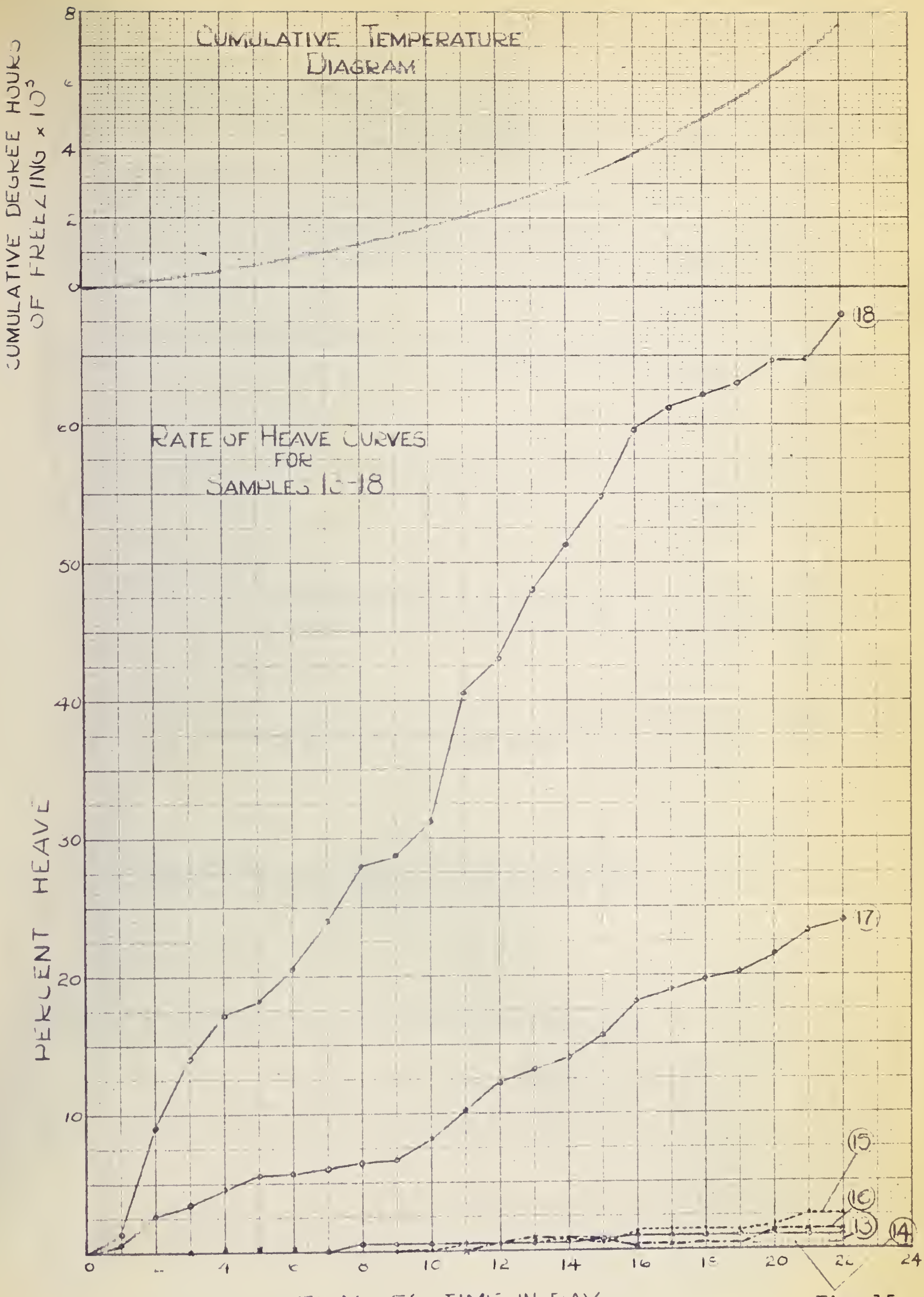

CUMULATIVE TEMPERATURE
DIAGRAM
CUMULATIVE DEGREE HOURS
OF FREEZING × 10³
RATE OF HEAVE CURVES
FOR
SAMPLES 13-18
PERCENT HEAVE
ELAPSED TIME IN DAYS
18
17
15
16
13
14
0
2
4
6
8
10
20
30
40
50
60
12
14
16
18
20
22
24

Fig. 15.

TABLE IV. SPECIMEN HEAVE DATA FOR SAMPLES 19 TO 25

Elapsed Time in Days	Water Temp. °C	Air Temp. °C	Accum. Degree Hours Freezing	Specimen Nos. 19 Heave	20 Heave	21 Heave	22 Heave	23 Heave	24 Heave	25 Heave
0	+17	0	0	0	0	0	0	0	0	0
1	+12	-3	72	0	0	0	0	0	0	0
2	+9	-6	216	18.35	0	0	0	0	0	0
3	+7	-8	308	25.8	0	0	0	0	0	0
4	+7	-7	476	35.8	0	0	0	0	0	0
5	+4	-7	644	45.8	0	0	0	0	0	0
6	+4	-8	836	56.1	0	0	0	1.00	0	0
7	+4	-8	1028	59.4	0.33	0	0	1.67	0	0
8	+4	-9	1244	59.4	0.33	0	0	2.50	0	0
9	Frozen	-8	1436	59.4	0.33	0	0	2.50	0	0
10	+7	-8	1628	51.6	1.67	1.17	0.83	2.50	0.17	0
11	+8	-14	2064	50.0	1.67	1.17	1.00	3.67	0.33	0.33
12	+8	-13	2376	50.0	2.00	1.17	1.33	4.17	0.33	0.83
13	+8	-15	2736	47.5	2.50	1.67	1.33	5.00	0.33	0.83
14	+28	-15	3096	42.5	2.50	1.67	1.33	2.50	0.33	0.83
15	+19	-15	3456	40.8	1.67	0.83	0	2.50	0.33	0
16	+9	-20	3936	35.0	2.50	1.00	1.33	7.50	2.00	0
17	+3	-22	4464	40.7	3.33	1.67	1.33	13.31	3.50	0.83
18	Frozen	-21	4968	46.4	3.67	1.67	1.33	17.18	6.84	0.83
19	+8	-22	5496	44.1	2.67	1.33	1.00	13.31	4.17	1.33
20	+8	-28	6168	42.8	2.67	1.33	1.67	12.50	3.50	1.67
21	+8	-30	6888	42.5	2.67	1.33	1.33	12.50	3.50	1.67
22	+7	-30	7608	42.5	3.00	1.67	2.16	12.50	3.50	1.67
Initial Moisture Content				13.1	12.6	13.0	12.2	13.4	13.2	13.5
Final Moisture Content				51.0	17.4	15.8	16.7	30.1	22.7	19.5
Initial Dry Density.				103.0	115.1	111.6	113.1	104.1	97.7	106.0
Initial Degree of Saturation				55.5	73.6	68.8	67.3	58.8	49.2	61.9
Heave Due to Pore Water Freezing:- Inches.				0.12	0.13	0.13	0.12	0.12	0.11	0.12
- %.				2.00	2.17	2.17	2.00	2.00	1.84	2.00
Admixture.				Nil	Aer. OTB	Aer. OTB	Aer. OTB	Aer. MA	Aer. MA	Aer. MA
Solution Strength (%).				0	11.9	23.1	36.9	11.2	22.7	33.3
Kinematic Viscosity.				1.8	----- Not available ------			3.4	9.2	19.6
Soil Used.				3	3	3	3	3	3	3

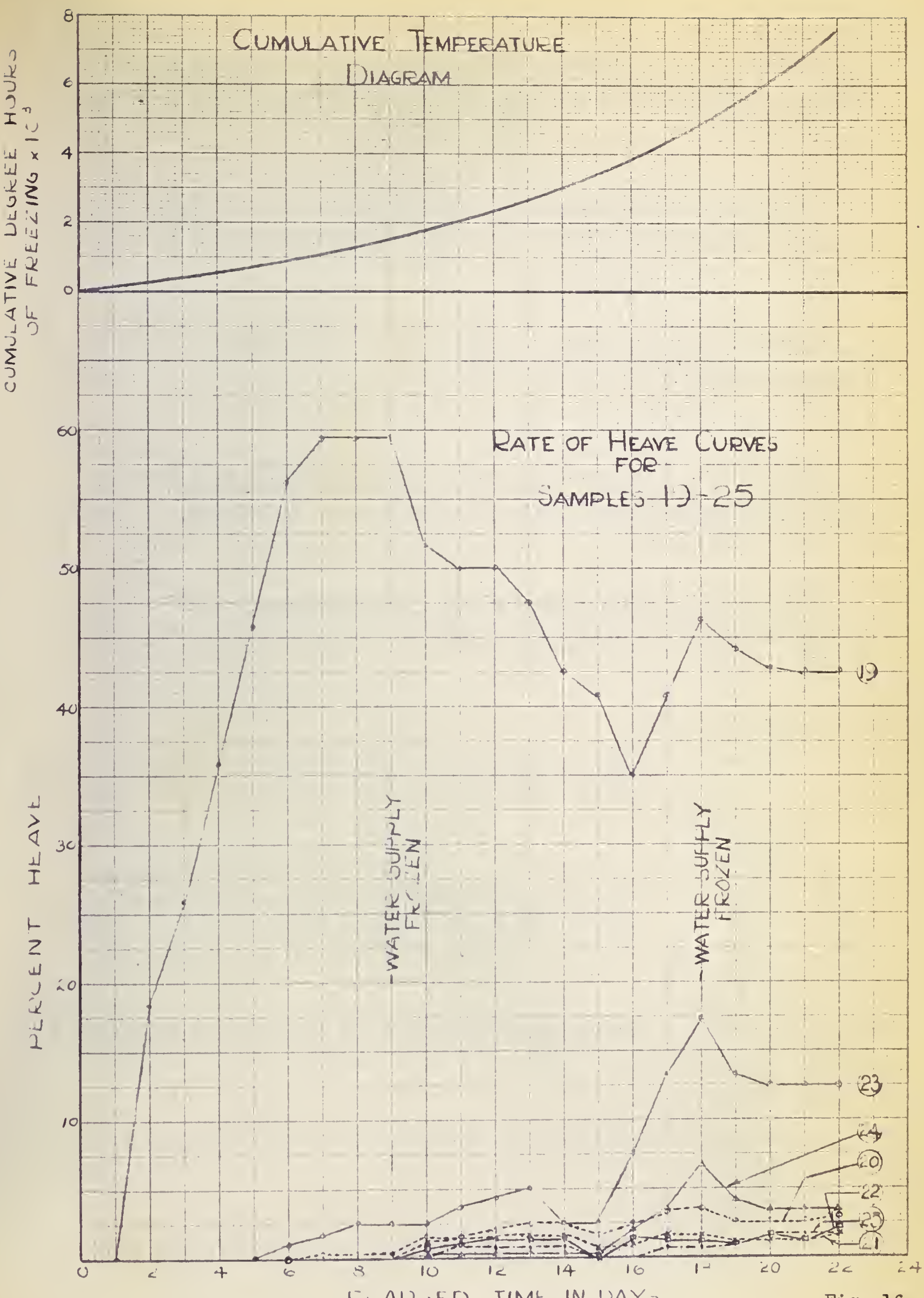

CUMULATIVE TEMPERATURE DIAGRAM
CUMULATIVE DEGREE HOURS OF FREEZING x 10³
RATE OF HEAVE CURVES FOR SAMPLES 19-25
PERCENT HEAVE
WATER SUPPLY FROZEN
WATER SUPPLY FROZEN
ELAPSED TIME IN DAYS
19
23
24
20
22
25
21

Fig. 16.

TABLE V. SPECIMEN HEAVE DATA FOR SAMPLES 26 TO 30

Elapsed Time in Days	Water Temp. °C	Air Temp. °C	Accum. Degree Hours Freezing	Specimen Nos. 26 Heave	27 Heave	28 Heave	29 Heave	30 Heave
0	+17	0	0	0	0	0	0	0
1	+12	-3	72	0	0	0	2.00	0.33
2	+9	-6	216	0	0	0	3.50	0.33
3	+7	-8	308	0	0.83	0	5.67	0.33
4	+7	-7	476	2.50	0.83	0	8.50	0.33
5.	+4	-7	644	4.17	1.33	0	10.33	0.33
6	+4	-8	836	8.50	2.83	0	12.18	0.33
7	+4	-8	1028	9.50	2.50	0	13.68	0.33
8	+4	-9	1244	10.00	4.17	0	15.68	0.33
9	Frozen	-8	1436	10.00	4.17	0	16.50	0.33
10	+7	-8	1628	6.17	2.17	0	12.00	0.33
11	+8	-14	2064	7.84	3.67	0	12.82	0.33
12	+8	-13	2376	8.33	3.67	0.33	13.66	0.33
13	+8	-15	2736	8.17	4.17	0.33	14.50	0.33
14	+28	-15	3096	5.00	2.50	0.33	16.17	0.33
15	+19	-15	3456	9.66	4.17	0.33	9.50	0.33
16	+9	-20	3936	15.18	7.50	1.67	12.82	0.33
17	+3	-22	4464	23.40	10.81	2.83	16.17	0.33
18	Frozen	-21	4968	25.50	13.67	3.17	19.50	0.33
19	+8	-22	5496	22.82	11.00	2.83	18.68	0.33
20	+8	-28	6168	22.50	11.00	2.83	17.18	0.33
21	+8	-30	6888	22.50	11.00	3.67	19.00	0.33
22	+7	-30	7608	22.50	11.00	3.67	21.20	0.33
Initial Moisture Content				13.4	13.0	14.5	31.4	11.9
Final Moisture Content				33.0	28.9	20.4	49.5	14.4
Initial Dry Density.				113.4	113.8	117.1	90.0	118.7
Initial Degree of Saturation				74.5	72.8	89.5	97.3	76.2
Heave Due to Pore Water Freezing:-			Inches.	0.13	0.13	0.15	0.24	0.12
-			%.	2.17	2.17	2.50	4.00	2.00
Admixture.				Aer. TEF	Aer. TEF	Aer. TEF	Lig. BD	Lig. XD
Solution Strength (%).				11.2	23.1	30.1	6.0	68.0
Kinematic Viscosity.				3.1	6.7	10.2	2.0	25.0
Soil Used.				3	3	3	4	3

Note: Sample 29 impregnated by electro-osmosis.

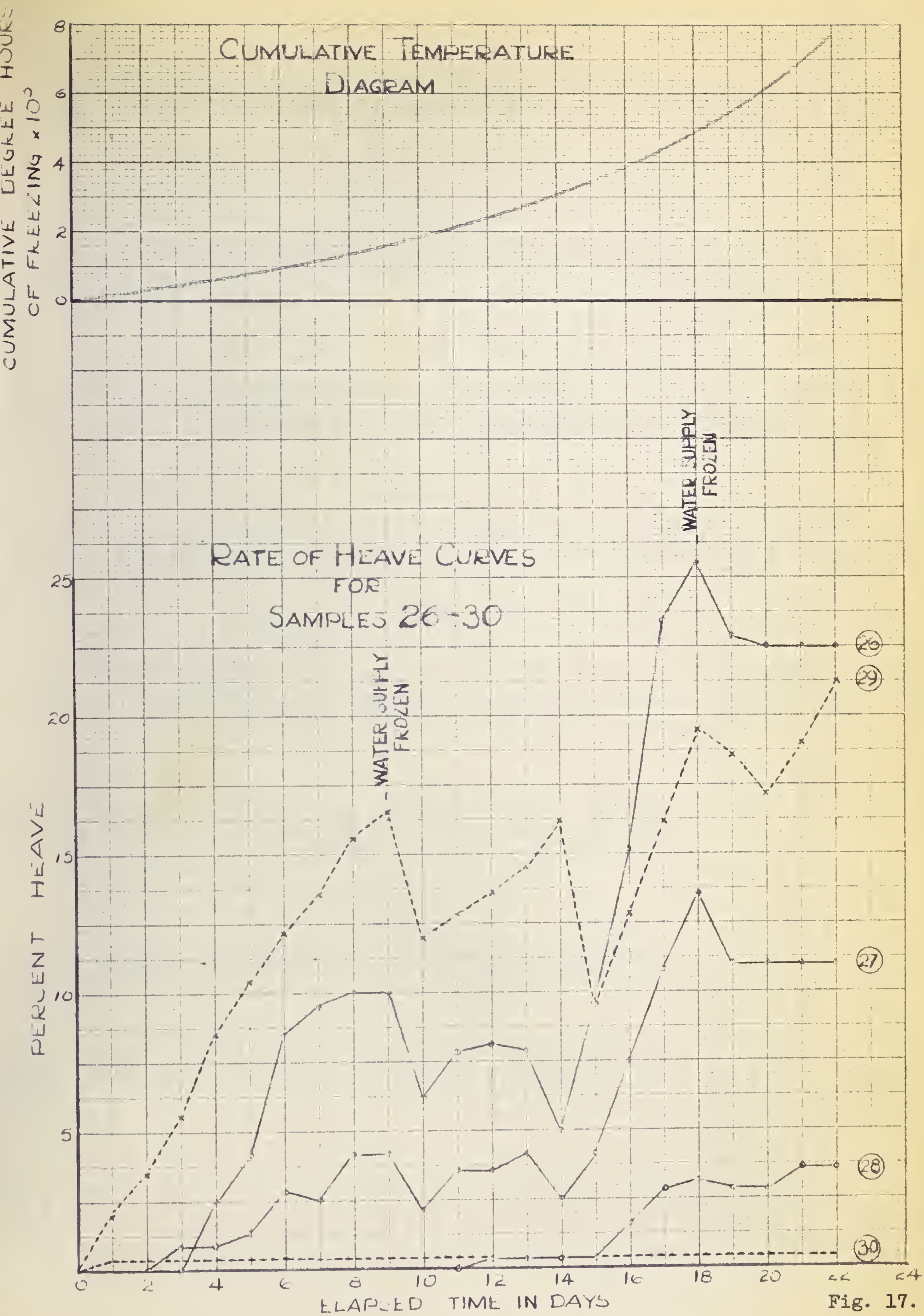

CUMULATIVE TEMPERATURE DIAGRAM
CUMULATIVE DEGREE HOURS OF FREEZING × 10³
RATE OF HEAVE CURVES FOR SAMPLES 26-30
WATER SUPPLY FROZEN
WATER SUPPLY FROZEN
PERCENT HEAVE
ELAPSED TIME IN DAYS
26
27
28
29
30

Fig. 17.

TABLE VI. SPECIMEN HEAVE DATA FOR SAMPLES 31 TO 35

Elapsed Time in Days	Water Temp. °C	Air Temp. °C	Accum. Degree Hours Freezing	Specimen Nos. 31 Heave	32 Heave	33 Heave	34 Heave	35 Heave
0	+24	0	0	0	0	0	0	0
1	+7	-10	240	4.17	0.17	2.00	0.83	0
2	+7	-17	648	9.17	0.17	5.34	0.83	0.83
3	+7	-22	1176	13.34	0.17	7.50	0.83	1.17
4	+7	-28	1848	18.33	0.17	10.32	0.83	1.83
5	+7	-8	2040	11.66	0	7.00	0.83	1.33
6	+7	-28	2712	20.82	0	10.32	1.17	1.33
7	+7	-24	3288	20.82	0	10.32	1.17	1.33
8	+7	-26	3912	26.7	0	13.22	2.00	2.17
9	+5	-22	4440	22.8	0.17	11.61	0.83	1.83
10	+4	-22	4968	27.5	0.50	17.00	1.67	2.17
11	+5	-28	5640	29.2	1.67	19.51	2.50	2.17
12	+5	-26	6264	29.2	1.67	20.35	2.50	2.17
13	+5	-32	7032	30.0	1.67	20.35	2.50	2.17
14	+5	-25	7632	31.7	0	22.00	2.50	3.00
15	+4	-27	8280	33.3	0	22.35	2.50	3.00
16	+4	-30	9000	34.2	0	23.70	3.34	3.34
17	+4	-29	9696	34.2	2.83	24.50	5.00	3.84
18	+3	-29	10392	35.8	3.33	26.20	5.00	3.84
19	+3	-29	11088	37.5	4.17	27.82	5.00	4.67
20	+4	-29	11784	39.2	5.00	28.70	5.00	6.34
21	+4	-30	12504	39.2	5.00	29.50	5.00	6.34
22	+3	-30	13224	40.9	5.00	30.38	5.84	6.34
23	+4	-29	13920	40.0	5.00	30.38	5.84	6.34
24	+3	-29	14616	41.7	5.00	30.38	5.84	6.34
25	+4	-29	15312	41.7	5.00	30.38	5.84	6.34
Initial Moisture Content				18.5	17.6	18.8	16.4	19.4
Final Moisture Content				39.0	32.4	31.5	19.0	35.2
Initial Dry Density.				98.0	93.4	96.7	101.9	98.0
Initial Degree of Saturation				69.5	59.0	68.5	67.7	72.8
Heave Due to Pore Water Freezing:-Inches. .				0.16	0.14	0.16	0.14	0.16
- %. .				2.67	2.33	2.67	2.33	2.67
Admixture.				Nil	Lig. BD	Aer. ??	Calgon	Sugar Beet Molasses
Solution Strength (%).				0	28.4	26.6	30.5	25.8
Kinematic Viscosity.				1.8	5.0	----	5.9	3.0
Soil Used.				Fallis	Fallis	Fallis	Fallis	Fallis

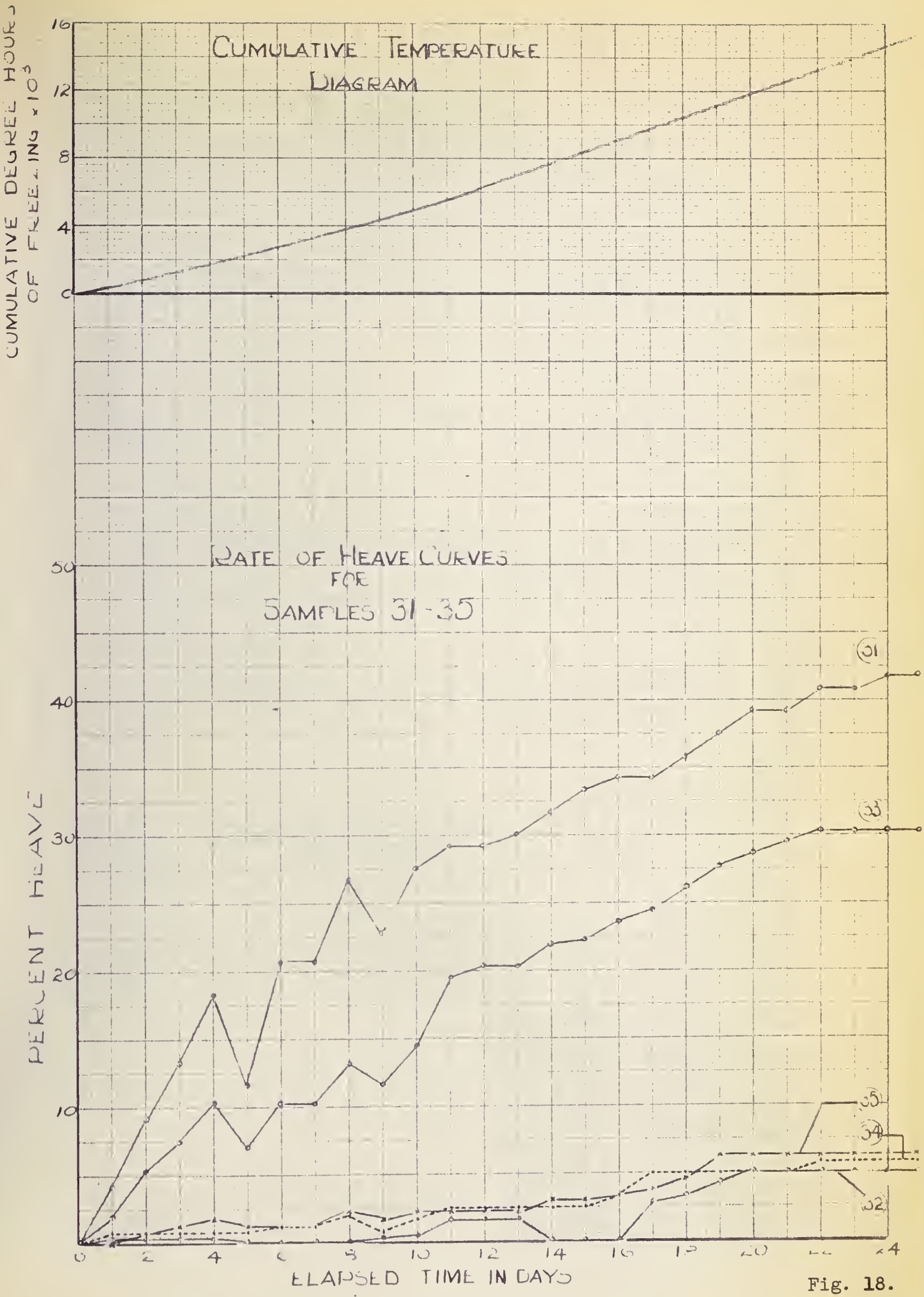

CUMULATIVE TEMPERATURE DIAGRAM
CUMULATIVE DEGREE HOURS OF FREEZING × 10³
RATE OF HEAVE CURVES FOR SAMPLES 31-35
PERCENT HEAVE
ELAPSED TIME IN DAYS
31
32
33
34
35

Fig. 18.

TABLE VII. SPECIMEN HEAVE DATA FOR SAMPLES 37 TO 42

Elapsed Time in Days	Water Temp. °C	Air Temp. °C	Accum. Degree Hours Freezing	Specimen Nos. 37 Heave	38 Heave	39 Heave	40 Heave	41 Heave	42 Heave
0	+7	0	0	0	0	0	0	0	0
1	+7	-10	240	0	0	0	1.50	2.17	1.17
2	+7	-10	480	0	0	0	1.50	2.34	5.34
3	+7	-10	720	0	0	0	2.17	2.50	6.17
4	+6	-9	936	0	0	0	3.17	3.34	6.50
5	+8	-11	1200	0	0.67	0	3.17	3.67	7.50
6	+6	-14	1536	0	0.67	0	5.34	4.17	12.31
7	+6	-15	1896	0	0.67	0	5.34	5.00	14.00
8	+6	-32	2664	0					
9	+6	-32	3432	0	1.33	0	8.00	7.50	33.20
10	+6	-27	4080	0	1.33	0	8.67	7.84	35.60
11	+6	-29	4776	0	1.33	0.50	10.32	9.18	37.30
12	+6	-28	5444	0	1.33	0.50	10.32	9.50	37.30
Initial Moisture Content				13.3	15.3	18.0	20.0	19.0	20.9
Final Moisture Content				14.4	16.0	18.0	23.4	24.6	39.7
Initial Dry Density.				110.0	108.3	101.8	100.9	102.7	103.1
Initial Degree of Saturation				67.8	74.1	74.5	80.8	80.3	89.5
Heave Due to Pore Water Freezing:- Inches..				0.14	0.16	0.18	0.20	0.19	0.20
- - %..				2.34	2.67	3.00	3.34	3.17	3.34
Admixture.				Lig. BD	Lig. BD	Lig. BD	Lig. BD	Lig. BD	Water
Solution Strength (%).				40	30	20	10	5	0
Kinematic Viscosity.				9.0	5.6	3.6	2.3	2.0	1.8
Soil Used.				3	3	3	3	3	3

Notes: Heaves in percent of six inch length.
Heaves due to pore water freezing in percent of six inch length.

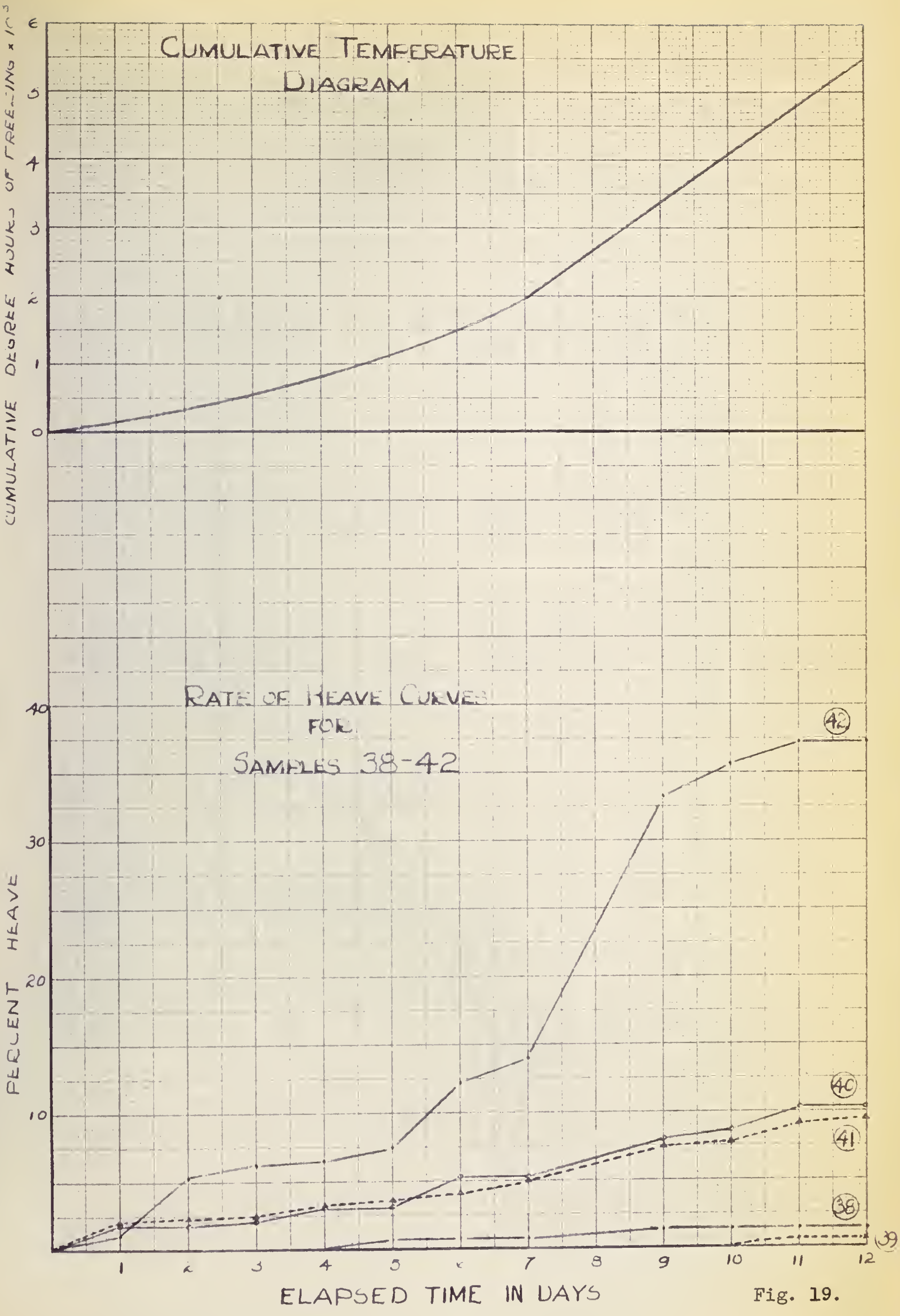

CUMULATIVE TEMPERATURE DIAGRAM
CUMULATIVE DEGREE HOURS OF FREEZING x 10³
RATE OF HEAVE CURVES FOR SAMPLES 38-42
PERCENT HEAVE
ELAPSED TIME IN DAYS
42
40
41
38
39

Fig. 19.

TABLE VIII. SPECIMEN HEAVE DATA FOR SAMPLES 43 TO 46

Elapsed Time in Days	Water Temp. °C	Air Temp. °C	Accum. Degree Hours Freezing	Specimen Nos.			
				43 Heave	44 Heave	45 Heave	46 Heave
0	+8	0	0	0	0	0	0
1	+3	-10	240	21.7	5.82	0.80	0
2	+1	-10	480	30.8	8.33	1.67	0
3	+1	-10	720	35.8	8.33	22.67	0
4	+2	-9	936	33.3	8.33	2.67	0
5	+7	-11	1200	34.2	9.33	3.84	0
6	+1	-14	1536	35.8	9.66	4.50	0
7	+2	-15	1896	35.8	9.66	4.50	0
8	+3	-32	2664				
9	+3	-32	3432	36.7	10.00	5.84	0.83
10	+4	-27	4080	35.8	9.50	5.00	0.83
11	+3	-29	4776	35.8	9.50	5.00	0.83
12	+3	-28	5444	36.2	10.0	5.00	0.83
Initial Moisture Content				12.9	14.2	14.6	16.3
Final Moisture Content				66.0	30.6	30.2	30.5
Initial Dry Density.				92.8	100.0	107.5	104.0
Initial Degree of Saturation				42.8	56.6	69.5	71.0
Heave Due to Pore Water Freezing: Inches				0.12	0.14	0.15	0.16
- %				2.00	2.33	2.50	2.67
Admixture.				Nil	Aer. No. 22	Aer. No. 22	Aer. No. 22
Solution Strength (%).				0	10.6	20.6	27.6
Kinematic Viscosity.				1.8	2.0	.2.3	2.5
Soil Used.				3	3	3	3

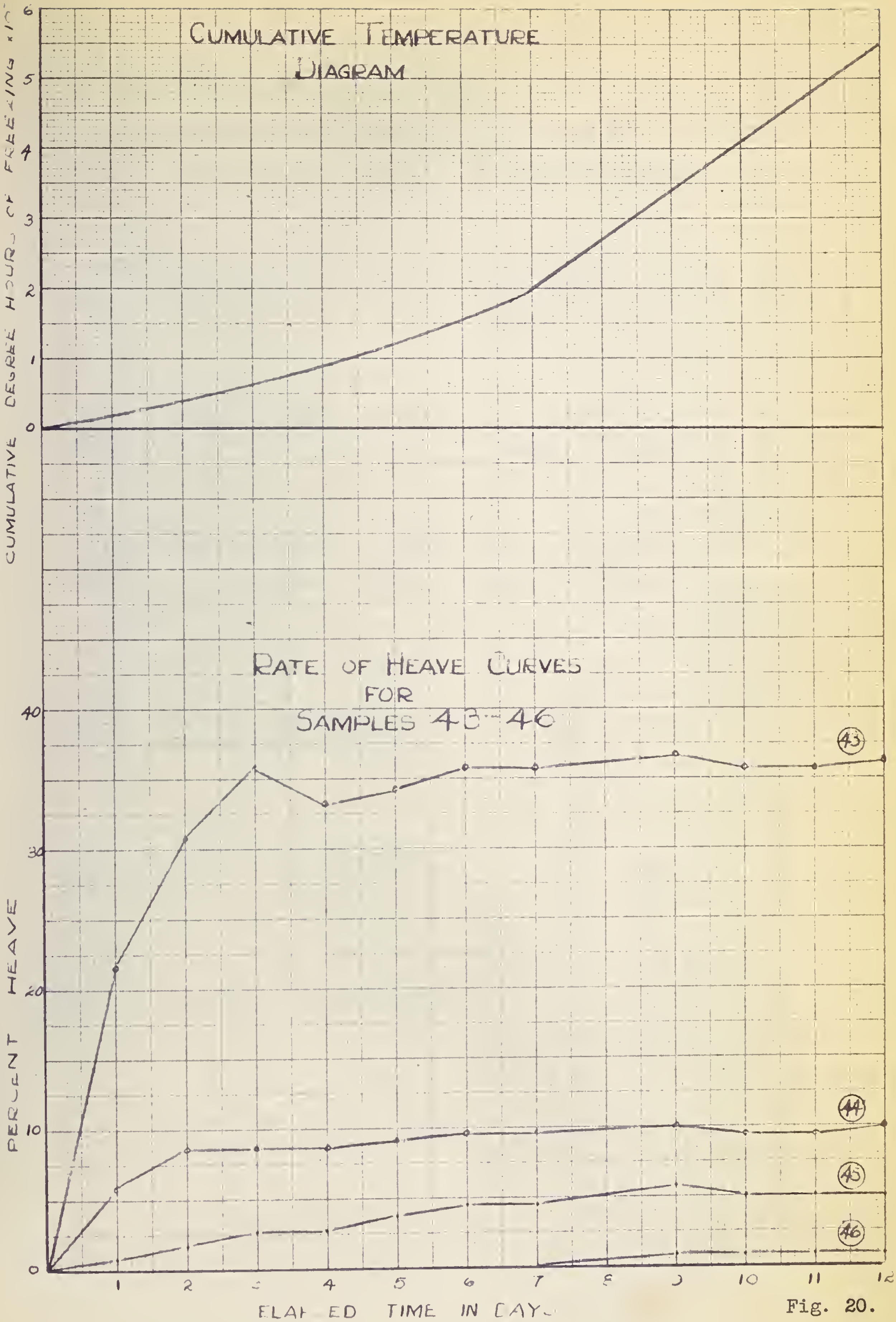
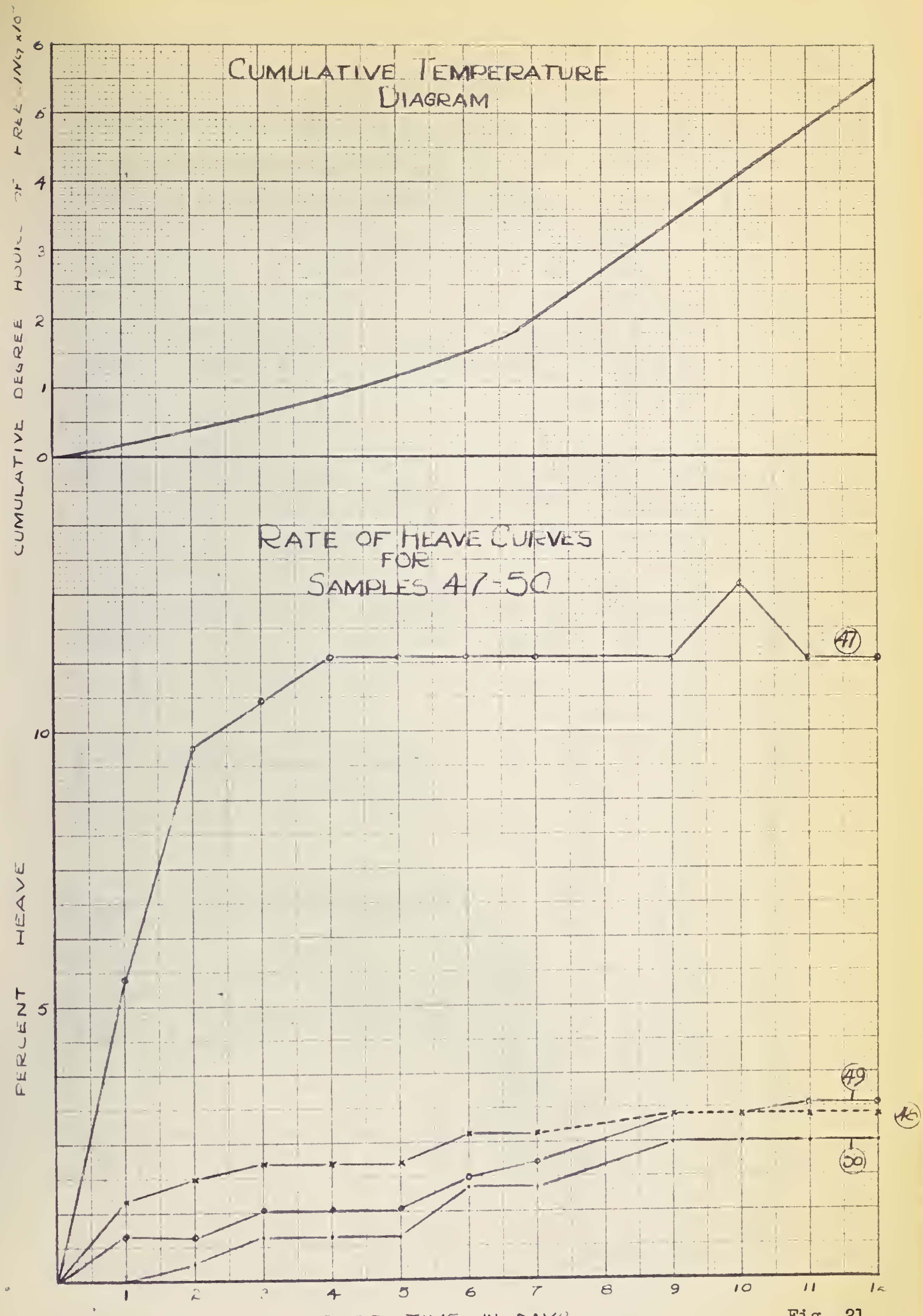

CUMULATIVE TEMPERATURE DIAGRAM
RATE OF HEAVE CURVES FOR SAMPLES 43-46
CUMULATIVE DEGREE HOURS OF FREEZING
PERCENT HEAVE
ELAPSED TIME IN DAYS
43
44
45
46

Fig. 20.

TABLE IX. SPECIMEN HEAVE DATA FOR SAMPLES 47 TO 50

Elapsed Time in Days	Water Temp. °C	Air Temp. °C	Accum. Degree Hours Freezing	Specimen Nos. 47 Heave	48 Heave	49 Heave	50 Heave
0	+8	0	0	0	0	0	0
1	+3	-10	240	5.50	1.33	0.83	0
2	+1	-10	480	9.67	1.83	0.83	0.33
3.	+1	-10	720	10.51	2.17	1.33	0.83
4	+2	-9	936	11.34	2.17	1.33	0.83
5	+7	-11	1200	11.34	2.17	1.33	0.83
6	+1	-14	1536	11.34	2.67	1.83	1.67
7	+2	-15	1896	11.34	2.67	2.17	1.67
8	+3	-32	2664				
9	+3	-32	3432	11.34	3.00	3.00	2.50
10	+4	-27	4080	12.68	3.00	3.00	2.50
11	+3	-29	4776	11.34	3.00	3.17	2.50
12	+3	-28	5444	11.34	3.00	3.17	2.50
Initial Moisture Content				21.5	21.3	19.7	20.4
Final Moisture Content				29.7	31.6	28.9	32.1
Initial Dry Density.				108.4	102.1	107.5	103.0
Initial Degree of Saturation				100.0	86.0	91.0	84.0
Heave Due to Pore Water Freezing:- Inches.				0.11	0.21	0.20	0.20
- %.				1.83	3.50	3.33	3.33
Admixture.				Nil	Lig. BD	Lig. BD	Lig. BD
Solution Strength.				0	10	20	30
Kinematic Viscosity.				1.8	2.3	3.6	5.6
Soil Used.				4	4	4	4

Note: Impregnated by electro-osmosis (All Samples).



CUMULATIVE TEMPERATURE DIAGRAM
RATE OF HEAVE CURVES FOR SAMPLES 47-50
CUMULATIVE DEGREE HOURS OF FREEZING x10
PERCENT HEAVE
ELAPSED TIME IN DAYS
0
1
2
3
4
5
6
10
5
1
2
3
4
5
6
7
8
9
10
11
12
47
49
48
50

Fig. 21.

TABLE X. SPECIMEN HEAVE DATA FOR SAMPLES 51 TO 54

Elapsed Time in Days	Water Temp. °C	Air Temp. °C	Accum. Degree Hours Freezing	Specimen Nos. 51 Heave	52 Heave	53 Heave	54 Heave
0	+8	0	0	0	0	0	0
1	+3	-10	240	3.34	8.33	8.33	2.50
2	+1	-10	480	4.17	8.84	9.17	7.00
3	+1	-10	720	4.17	9.33	10.00	10.82
4	+2	-9	936	4.67	10.32	10.82	11.50
5	+7	-11	1200	5.00	11.00	11.17	12.00
6	+1	-14	1536	5.00	12.50	12.50	12.50
7	+2	-15	1896	5.84	12.50	12.50	12.50
8	+3	-32	2664				
9	+3	-32	3432	5.84	14.18	14.18	14.18
10	+4	-27	4080	5.84	14.18	15.50	14.50
11	+3	-29	4776	5.84	14.18	15.82	14.50
12	+3	-28	5444	5.84	14.18	15.82	14.50
Initial Moisture Content				13.5	12.8	13.3	13.3
Final Moisture Content				30.9	36.9	30.8	29.5
Initial Dry Density.				100.2	98.0	103.7	106.5
Initial Degree of Saturation				53.6	48.0	57.5	
Heave Due to Pore Water Freezing:- Inches. .				0.13	0.12	0.13	
- %. .				2.17	1.83	2.17	
Admixture.				Na_2CO_3	Na_2CO_3	Na_2CO_3	Lignosol Layer
Solution Strength.				7.4	26.4	22.5	20.0
Kinematic Viscosity.							3.6 (Layer)
Soil Used.				3	3	3	3
Admixture as percentage of dry soil.				1	3	5	----

Note: Specimen No. 54 - Lignosol layer in lucite rings 4 & 5.

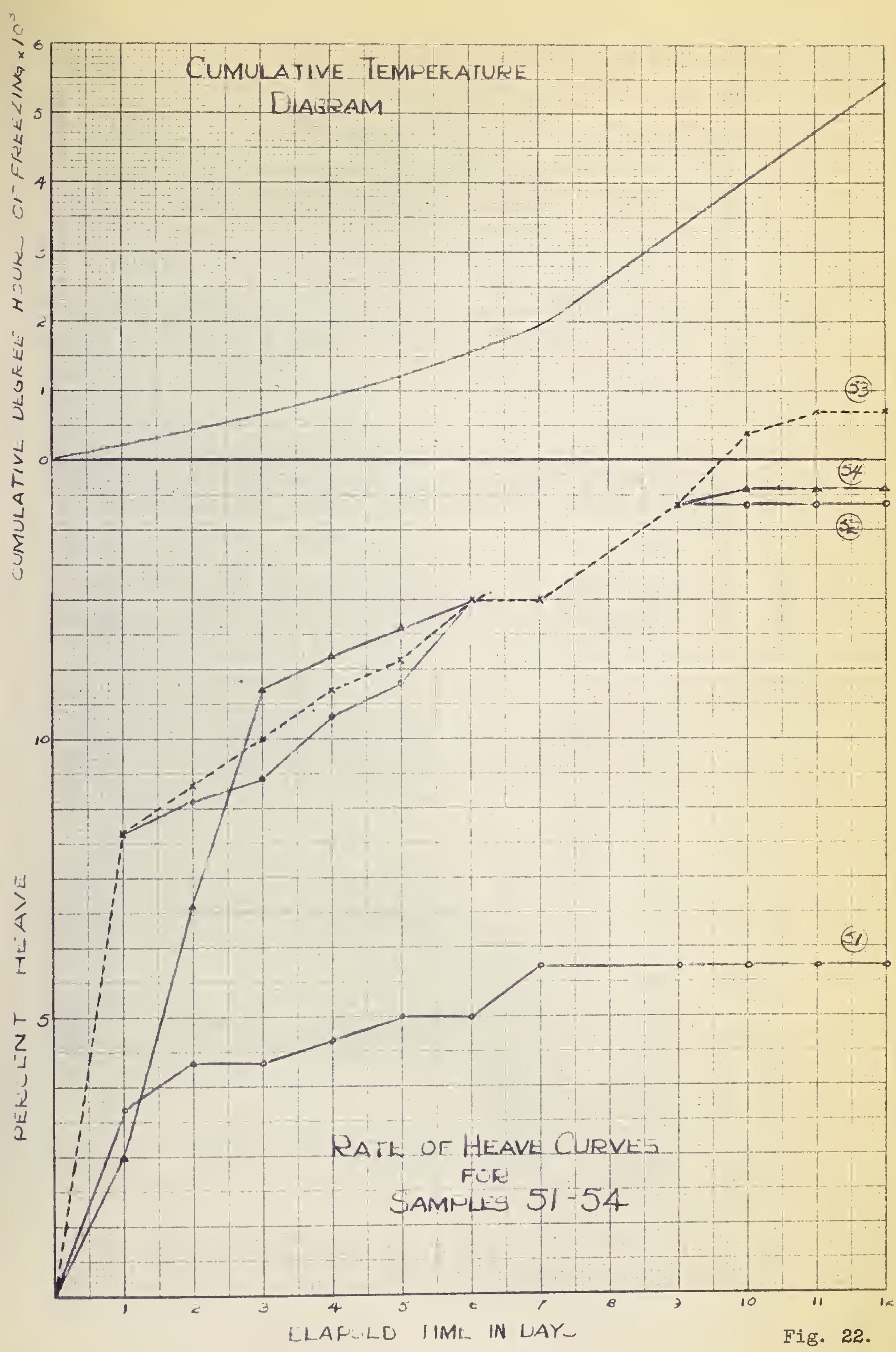

CUMULATIVE TEMPERATURE
DIAGRAM
CUMULATIVE DEGREE HOURS OF FREEZING x 10³
PERCENT HEAVE
RATE OF HEAVE CURVES
FOR
SAMPLES 51-54
ELAPSED TIME IN DAYS
51
52
53
54
0
1
2
3
4
5
6
10
7
8
9
11
12

Fig. 22.

TABLE XI. SPECIMEN HEAVE DATA FOR SAMPLES 55 - 60

Elapsed Time in Days	Water Temp. °C	Air Temp. °C	Accum. Degree Hours Freezing	Specimen Nos. 55 Heave	56 Heave	57 Heave	58 Heave	59 Heave	60 Heave
0	0	0	0	0	0	0	0	0	0
1	+8	-3	72	0	0	1.17	0.67	0	0
2	+8	-5	192	0	4.67	1.17	2.34	0.33	0
3	+8	-4	288	0	5.84	1.17	3.33	1.00	0
4	+6	-7	456	9.83	8.84	3.33	4.84	2.83	0
5	+6	-7	624	9.83	9.17	4.17	4.84	2.83	0
6	+6	-10	864	9.83	10.17	4.17	4.84	3.67	0.33
7	+5	-10	1104	10.67	11.00	6.67	5.67	4.50	0.33
8	+5	-10	1344	19.85	12.16	7.50	7.34	5.34	1.67
9	+5	-18	1776	33.20	18.82	10.00	9.00	6.17	1.67
10	+5	-18	2208	41.50	21.68	12.50	9.00	8.17	3.33
11	+5	-18	2640	44.20	21.68	12.50	9.00	8.17	3.33
12	+5	-22	3168	46.50	21.68	14.18	10.82	8.17	3.33
Initial Moisture Content				24.5	25.5	23.5	23.7	22.9	22.4
Final Moisture Content				24.5	26.7	31.7	38.1	42.9	30.6
Initial Dry Density.				97.4	95.6	95.3	95.7	97.9	95.5
Initial Degree of Saturation				90.7	90.6	82.6	84.0	85.4	79.0
Heave Due to Pore Water Freezing:- Inches.				0.21	0.21	0.19	0.20	0.19	0.19
%.				3.50	3.50	3.17	3.34	3.17	3.17
Admixture.				Nil	Lig. BD	Lig. BD	Lig. BD	Lig. BD	Lig. BD
Solution Strength (%).				0	1	2	4	6	10
Kinematic Viscosity.				1.8	1.8	1.9	2.0	2.1	2.4
Soil Used.				3	3	3	3	3	3

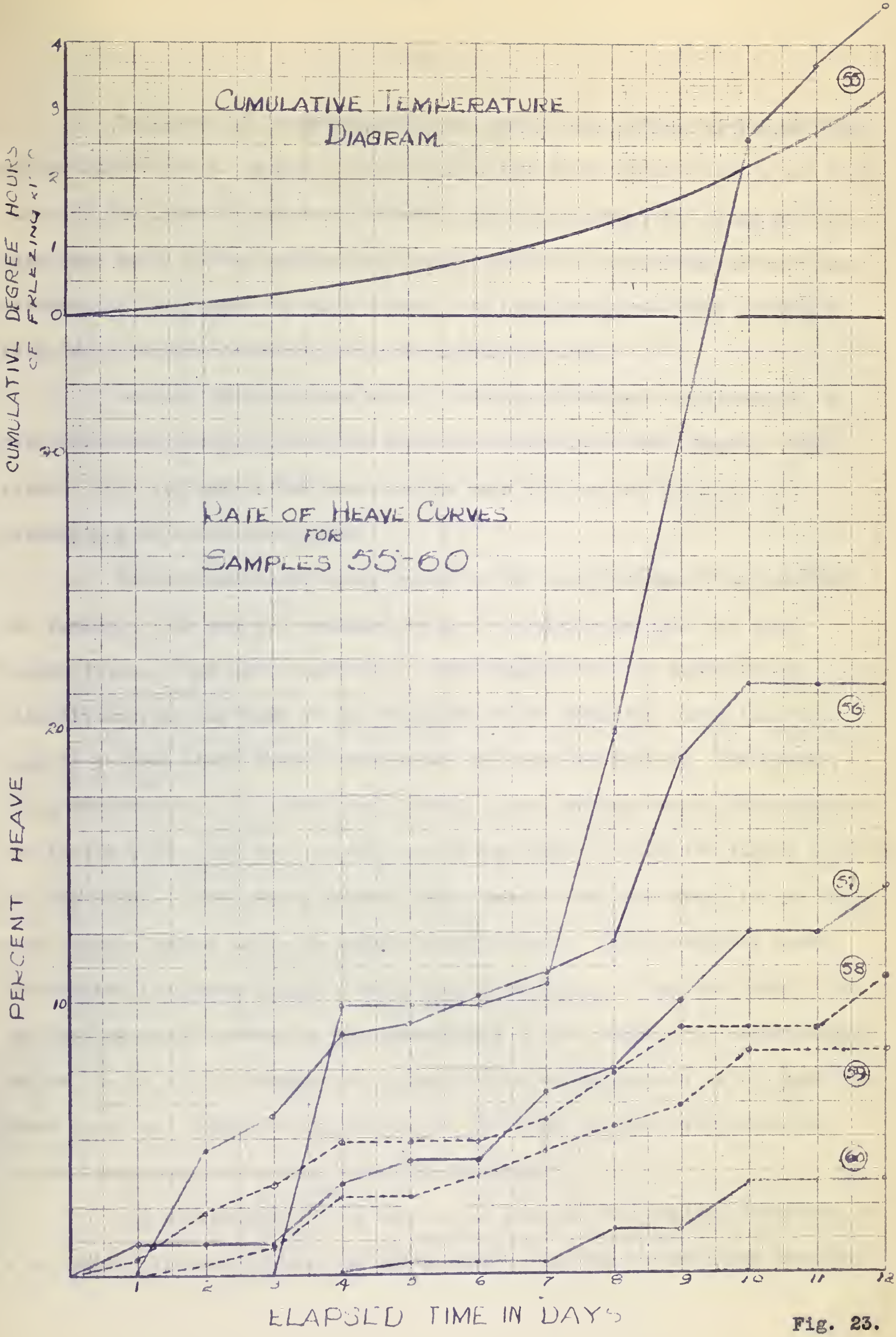

CUMULATIVE TEMPERATURE DIAGRAM
CUMULATIVE DEGREE HOURS OF FREEZING
RATE OF HEAVE CURVES FOR SAMPLES 55-60
PERCENT HEAVE
ELAPSED TIME IN DAYS
0
1
2
3
4
10
20
30
1
2
3
4
5
6
7
8
9
10
11
12
55
56
57
58
59
60

Fig. 23.

The areas of ice segregation are quite well defined by the parting of the lucite rings. However, the depth of the frost penetration is not indicated by the lower boundary of the area, since the bottom few rings may have been held solid by the surrounding frozen zonolite, which would prevent any movement of the rings. In such a case, the heaving forces would produce a relative movement of the soil and the confining rings.

Aerosol OTB solutions were of a thick gelatinous consistency. A one-half percent solution was the optimum solubility at zero degrees centigrade. For this reason the computations were not carried through, as viscosities were indeterminable.

The original water-bath heater in the twelve-sample Frost Cabinet was faulty. This was not realized until the second time that the bath became frozen. The heave pattern for the samples 19 to 30 indicates a discontinuity at the time of the freezing of the bath, but shows that the samples resumed their former trend after the bath was melted. The heater, being thermostatically controlled, heated to its maximum output while melting the ice, and in doing so, probably heated the water bath to the higher limit of its set range. This would, in turn, melt some of the ice lenses in the specimens to some height above the sample-holding board. The specimens, being without the ice-lense support, would settle slightly. From this point, all the heaving would be done in the lower parts of the sample, but as mentioned before, would not necessarily be apparent from the appearance of the specimen. There would not likely be any parting of the rings in this area since the frozen insulation would have held them stationary.

The termination of the heaving in some of the samples, indicated by a horizontal line on the rate of heave curves, was due to the frost penetra-

tion being down to the bottom of the samples, with no further capillary action in the samples.

It should be realized that the treatment of all the test data was done on the basis that the permeabilities of all the specimens in any "set" would be identical but for the presence of the admixtures. Since the permeability is a function of the void spaces in the soil, it is also a function of the dry density of the soil. For this reason an attempt was made to create equal densities in all the samples. This was done by tamping the soil into the molds in a systematic manner, and with due regard to the mechanics of compaction. Generally the densities were quite close to one another and the associated effect on the permeability of the soil was considered to have been made a constant for all the samples.

Meaning of Terms:

Water Temperature: Temperature of the water bath (Fig. 2) supplying water to the samples.

Air Temperature: Temperature of the air directly above the samples.

Accum. Degree Hours of Freezing: The cumulative sum of the number of degree hours of freezing up to the elapsed time shown, i.e., -3°C. for one day is 72 degree hours of freezing.

Heave: All heaves are tabulated as the change in length of the sample expressed as a percentage of the original length. The change in length is the total change from the beginning of the freezing test and is not an incremental change.

Initial Moisture Content: Representative samples of each specimen were taken at the time of molding. All moisture contents are expressed as the weight of water divided by the dry weight of soil, and are presented as percentages.

Final Moisture Content: This was obtained by using the whole specimen as a moisture content sample. Samples 7 to 12 were broken into layers and the moisture content variations determined (Table II(a)).

Initial Dry Density: This is an expression of the state of compactness of the soil having units of lbs. per cu. ft.

Initial Degree of Saturation: This value expresses, as a percentage, that amount of fluid which the soil holds as compared to the amount which it is capable of holding in its particular state of density. It is the percentage of the void spaces which are filled with water.

Heave due to Pore Water Freezing: This is the maximum amount of heaving attributable to the expansion of the pore water on freezing. The sample does not necessarily exhibit this amount of heave since the degree of saturation may or may not be a factor involved. The soil water, on freezing, may in some cases tend to fill a larger portion of the void spaces in the soil, whereas in others the voids might remain unaltered and the full effect of the expansion would be revealed by the heaving of the sample.

Solution Strength: Weight of the admixture divided by the weight of water, expressed as a percentage.

Soil Used: Figures 9 & 28 show the grain size curves of all the soils used and are referred to by number.

8. Correlation of Data with Theoretical Concepts

It was noticed throughout the program that the specimens were very sensitive to slight room-temperature increases. If, for some reason, the cold-room door was not closed securely, the temperature would rise. The samples generally showed a corresponding settlement. In other cases the

TABLE XII. MAXIMUM HEAVE RATE

(1) Specimen Number	(2) Admixture	(3) Solution Strength	(4) Viscosity of Solution	(5) Period of Max. Rate of Heave	(6) Max. Heave During This Period - %	(7) Degree Hours of Freezing During This Period	(8) Percent Heave Per 1000 Degree Hours	(9) (4) x (8)	(10) Degree of Saturation
1	Lig. BD	68.0	50	14 to 16	1.7	938	1.81	90.5	19.8
2	"	55.5	22.5	14 to 16	2.5	938	2.66	60.0	20.1
3	"	42.5	10.1	14 to 16	2.0	938	2.13	21.5	21.9
4	"	28.0	5.0	18 to 19	2.8	310	9.04	45.2	28.5
5	"	4.0	2.0	12 to 14	4.2	528	7.95	15.9	33.5
6	Nil	0	1.8	12 to 14	4.2	528	7.95	14.3	28.2
7	Lig. XD	68.0	25.0	0 to 9	5.2	6816	0.76	19.0	30.1
8	"	55.5	14.1	0 to 9	4.4	6816	0.65	9.1	41.3
9	"	42.5	7.5	0 to 9	6.0	6816	0.88	6.6	38.8
10	"	28.0	4.4	0 to 9	8.7	6816	1.28	5.6	42.1
11	"	4.0	2.0	0 to 6	11.0	4440	2.48	5.0	55.1
12	Nil	0	1.8	0 to 6	13.7	4440	3.09	5.6	47.1
13	Lig. XD	63.0	20.0	o to 22	1.00	7608	0.13	2.6	67.0
14	"	50.0	10.8	0 to 22	0.33	7608	0.04	0.4	78.8
15	"	42.0	7.3	0 to 22	2.67	7608	0.35	2.6	72.6
16	"	32.0	5.0	0 to 22	1.43	7608	0.19	1.0	75.5
17	"	4.0	2.0	0 to 22	24.00	7608	3.16	6.3	87.0
18	Nil	0	1.8	0 to 22	65.50	7608	8.61	15.3	85.9
19	Nil	0	1.8	1 to 6	56.1	764	73.5	132.4	55.5
20	Aer.OTB	11.9	Gel.	-------	-----	----	----	----	73.6
21	"	23.1	"	-------	-----	----	----	----	68.8
22	"	36.9	"	-------	-----	----	----	----	67.3
23	Aer. MA	11.2	3.4	15 to 18	14.68	1512	9.70	33.0	58.8
24	"	22.7	9.2	15 to 18	6.51	1512	4.30	39.6	49.2
25	"	33.3	19.6	16 to 19	1.67	2232	0.74	12.4	61.9
26	Aer.TEF	11.2	3.1	14 to 18	20.50	1872	10.95	33.9	74,5
27	"	23.1	6.7	14 to 18	11.17	1872	5.96	40.0	72.8
28	"	31.0	10.2	14 to 17	2.50	1368	1.83	18.7	89.5
29	Lig. BD	6.0	2.0	15 to 18	10.00	1512	6.61	13.2	97.3
30	Lig. XD	68.0	25.0	0 to 1	0.33	72	4.59	114.9	76.2

TABLE XII. MAXIMUM HEAVE (Concluded)

(1) Specimen Number	(2) Admixture	(3) Solution Strength	(4) Viscosity of Solution	(5) Period of Max. Rate of Heave	(6) Max. Heave During This Period - %	(7) Degree Hours of Freezing During This Period	(8) Percent Heave Per 1000 Degree Hours	(9) (4) x (8)	(10) Degree of of Saturation
31	Nil	0	1.8	0 to 4	18.33	1848	9.93	17.89	69.5
32	Lig. BD	28.4	5.0	16 to 17	2.83	696	4.07	20.35	59.0
33	Aerasol	----	---	--------	----	----	----	-----	----
34	Calgon	30.5	5.9	9 to 11	1.67	1200	1.39	8.2	67.7
35	Sugar Beet Molasses	25.8	3.0	16 to 20	3.00	2784	1.08	3.2	72.8
37	Lig. BD	40.0	9.0	NO HEAVE	----	----	----	----	67.8
38	"	30.0	5.6	7 to 9	0.67	1536	0.44	2.46	74.1
39	"	20.0	3.6	10 to 11	0.50	696	0.72	2.59	74.5
40	"	10.0	2.3	0 to 1	1.50	240	6.25	14.95	80.8
41	"	5.0	2.0	0 to 1	2.17	240	9.04	18.08	80.3
42	Nil	0	1.8	7 to 9	19.20	1536	12.50	22.50	89.5
43	Nil	0	1.8	0 to 1	21.7	240	90.40	163.	42.8
44	Aer.No.22	10.6	2.0	0 to 1	5.82	240	24.20	48.40	56.6
45	"	20.6	2.3	0 to 3	2.67	720	3.71	8.54	69.5
46	"	27.6	2.5	7 to 9	0.83	1536	0.54	1.35	71.0
47	Nil	0	1.8	0 to 1	5.50	240	22.90	41.30	100.0
48	Lig. BD	10.0	2.3	0 to 1	1.33	240	5.54	12.75	86.0
49	"	20.0	3.6	0 to 1	0.83	240	3.46	12.45	91.0
50	"	30.0	5.6	5 to 6	0.83	336	2.47	13.82	84.0
51	Na_2CO_3	7.4/ 1*							53.6
52	"	26.4/ 3*							48.0
53	"	22.5/ 5*							57.5
54	Lig.(BD)Layer	20.0	3.6						----
55	Nil	0	1.8	7 to 10	40.83	1104	36.9	66.4	90.7
56	Lig. BD	1	1.8	1 to 4	8.84	384	23.0	41.4	90.6
57	"	2	1.9	3 to 9	8.83	1488	6.0	11.4	82.6
58	"	4	2.0	0 to 4	4.84	456	10.6	21.2	84.0
59	"	6	2.1	3 to 4	1.83	168	10.9	22.3	85.4
60	"	10	2.4	7 to 8	1.34	240	5.6	13.5	79.0

* Solution strength by weight water / Percentage by weight of soil.

behavior was erratic for no obvious reason.

The relationship between the viscosity of the saturating fluid and the rate of heaving of the specimen was the required quantity. The viscosity of the admixture solutions was a non-varying, fixed value. However, the rate of heave was an ambiguous quantity. It was always expressed as a percentage per thousand degree-hours of freezing. Two rates of heaving were considered: (1) the average rate of heaving, and (2) the maximum rate of heaving. The maximum rate of heaving was found by choosing several points of a likely maximum rate from the rate of heave curves, and extracting the maximum from them. The degree days of freezing during this period was the difference between the cumulative totals at the beginning and end of the period. The average rate of heaving was considered to be the rate from the time the heaving began until the time that the curves became erratic. It would be the slope of a straight line joining the plotted heaves at these two times. Then, knowing the rate of heave and the viscosity, their product was computed. On the basis of the theory, excluding all other factors, the values found in this manner, for all specimens in any one set, should have been the same.

Whether the heaving due to the expansion of the pore water should be included in the analysis or not is unassessable. Indeed, some of the samples did not even heave to this extent totally. Therefore analyses were made with two varying factors.

Table XIII deals with the average rate of heave. To include the pore water expansion is to say that the heave due to this factor is not a true heave in the technical sense of the term; that is, the heave was not produced by the production of ice lenses by the action mentioned in the

TABLE XIII. AVERAGE HEAVE RATE

(1) Spec. No.	(2) Admixture	(3) Sol'n Str.	(4) Visc.	(5) Period of Heave	(6) Heave	(7) Expansion	(8) Heave Minus Expan.	(9) Degree Hours Freezing	(10) Heave Per 1000 Degree Hours-Based on Col. 6	(11) Heave Per 1000 Degree Hours-Based on Col. 8	(12) Col. 4 x Col.10	(13) Col. 4 x Col.11
1	Lig. BD	68.0	50.0	14 to 31	6.1	0.83	5.3	7630	0.80	0.70	40.0	34.7
2	"	55.5	22.5	11 to 30	7.0	0.83	6.2	7678	0.91	0.81	20.5	18.2
3	"	42.5	10.1	11 to 34	11.5	1.00	10.5	10654	1.08	0.99	10.9	10.0
4	"	28.0	5.0	11 to 30	9.3	1.00	8.3	7678	1.21	1.08	6.6	5.4
5	" "	4.0	2.0	12 to 34	19.2	1.33	17.9	10390	1.85	1.72	3.7	3.4
6	Nil	0	1.8	10 to 31	18.8	1.17	17.6	8638	2.18	2.04	3.9	3.7
7	Lig. XD	68.0	25.0	1 to 14	6.8	1.17	5.6	10008	0.68	0.56	17.0	14.0
8	"	55.5	14.1	0 to 20	8.0	1.33	6.7	14952	0.54	0.45	7.5	6.3
9	"	42.5	7.5	1 to 17	8.2	1.33	6.9	12240	0.67	0.57	5.0	4.3
10	"	28.0	4.4	0 to 16	10.8	1.50	9.3	12048	0.90	0.77	4.0	3.4
11	"	4.0	2.0	0 to 9	11.8	2.00	9.8	6816	1.73	1.44	3.5	2.9
12	Nil	0	1.8	0 to 9	14.0	1.80	12.2	6816	2.05	1.79	3.7	3.2
13	Lig. XD	63.0	20.0	0 to 16	1.0	2.00	----	3936	0.25	----	5.0	----
14	"	50.0	10.8	0 to 6	0.33	2.17	----	1028	0.32	----	3.5	----
15	"	42.0	7.3	3 to 21	2.67	2.33	0.34	6580	0.41	0.05	3.0	0.4
16	"	32.0	5.0	11 to 20	1.43	2.33	----	4104	0.36	----	1.8	----
17	"	4.0	2.0	0 to 22	24.00	2.84	21.16	7608	3.16	2.78	6.3	5.6
18	Nil	0	1.8	0 to 22	65.50	3.00	62.50	7608	8.60	8.31	15.6	15.0
19	Nil	0	1.8	1 to 7	59.40	2.00	57.4	956	62.00	60.00	111.8	108.0
20	Aer.OTB	11.9	Gel.	6 to 13	2.50	2.17	0.33	2100	1.19	0.16	----	----
21	"	23.1	"	9 to 13	1.67	2.17	----	1300	1.28	----	----	----
22	"	36.9	"	9 to 12	1.33	2.00	----	940	1.42	----	----	----
23	Aer. MA	11.2	3.4	5 to 18	17.18	2.00	15.18	4324	3.97	3.51	13.5	11.9
24	"	22.7	9.2	10 to 18	6.84	1.84	5.00	3340	2.04	1.50	19.0	13.8
25	"	33.3	19.6	11 to 20	1.67	2.00	-----	4104	0.41	-----	8.0	----
26	Aer.TEF	11.2	3.1	0 to 8	10.00	2.17	7.83	1244	8.04	6.28	24.9	19.5
27	"	23.1	6.7	0 to 18	13.67	2.17	11.50	4968	2.75	2.31	18.4	15.5
28	"	31.0	10.2	11 to 21	3.67	2.50	1.17	4824	0.76	0.24	7.8	2.5
29	Lig. BD	6.0	8.0	0 to 9	16.50	4.00	12.50	1436	11.50	8.71	23.0	17.4
30	Lig. XD	68.0	25.0	0 to 1	0.33	2.00	-----	72	4.59	-----	114.9	-----

TABLE XIII. AVERAGE HEAVE RATE (Concluded)

(1) Spec. No.	(2) Admixture	(3) Sol'n Str.	(4) Visc.	(5) Period of Heave	(6) Heave	(7) Expansion	(8) Heave Minus Expan.	(9) Degree Hours Freezing	(10) Heave Per 1000 Degree Hours-Based on Col. 6	(11) Heave Per 1000 Degree Hours-Based on Col. 8	(12) Col. 4 x Col.10	(13) Col. 4 x Col.11
31	Nil	0	1.8	0 to 24	41.70	2.67	39.03	14616	2.85	2.67	5.13	4.81
32	Lig. BD	28.4	5.0	16 to 20	5.00	2.33	2.67	2784	1.79	0.96	8.95	4.80
33	Aerasol	--	---	------	---	--	---	---	--	--	--	--
34	Calgon	30.5	5.9	0 to 22	5.84	2.33	2.51	13224	0.44	0.27	2.60	1.60
35	S.B.Mol.	25.8	3.0	1 to 19	4.67	2.67	2.00	11848	0.39	0.17	1.17	0.54
37	Lig. BD	40.0	9.0	NO HEAVE	---	--	--	---	--	--	--	--
38	"	30.0	5.6	4 to 9	1.33	2.67	--	2496	0.53	--	2.97	--
39	"	20.0	3.6	10 to 11	0.50	3.00	--	696	0.72	--	2.59	--
40	"	10.0	2.3	0 to 11	10.32	3.34	6.98	4776	2.16	1.47	4.98	3.38
41	"	5.0	2.0	0 to 12	9.50	3.17	6.33	5444	1.75	1.17	3.50	2.34
42	Nil	0	1.8	0 to 11	37.30	3.34	33.96	4776	7.81	4.34	14.08	7.80
43	Nil	0	1.8	0 to 3	35.80	2.00	33.80	720	49.8	47.0	89.7	84.5
44	Aer.No.22	10.6	2.0	0 to 2	8.33	2.33	6.00	480	17.4	12.5	34.8	25.0
45	"	20.6	2.3	0 to 9	5.84	2.50	3.34	3432	1.70	0.98	3.91	2.25
46	"	27.6	2.5	7 to 9	0.83	2.67	--	336	2.47	--	13.82	--
47	Nil	0	1.8	0 to 4	11.34	1.83	9.51	936	12.11	10.15	21.9	18.3
48	Lig. BD	10.0	2.3	0 to 9	3.00	3.50	--	3432	0.87	--	2.00	--
49	"	20.0	3.6	0 to 11	3.17	3.33	--	4776	0.66	--	2.37	--
50	"	30.0	5.6	0 to 9	2.50	3.33	--	3432	0.73	--	4.09	--
51	Na_2CO_3	7.4/ 1*										
52	"	26.4/ 3*										
53	"	22.5/ 5*										
54	Lig.(BD) Layer		3.6									
55	Nil	0	1.8	7 to 12	35.83	3.50	32.33	2064	17.34	15.65	31.2	28.2
56	Lig. BD	1	1.8	1 to 10	21.68	3.50	18.18	2136	10.16	8.52	18.3	13.4
57	"	2	1.9	3 to 11	11.33	3.17	8.16	2352	4.81	3.47	9.2	6.6
58	"	4	2.0	0 to 12	10.82	3.34	7.48	3168	3.42	2.36	6.8	4.7
59	"	6	2.1	1 to 10	8.17	3.17	5.00	2136	3.83	2.34	8.1	4.9
60	" "	10	2.4	7 to 10	3.00	3.17	--	1104	2.67	0	6.5	0

* Solution Strength by weight water / Percentage Admixture by weight of soil.

general opening remarks. Therefore the heave attributable to this factor would be subtracted from the total heave, and the remainder carried through the table. Ignoring this factor, the maximum heave was carried through as a comparison to the corrected heave. Table XII shows the results obtained by using a maximum rate of heave, and Table XIII the average rate of heave. The tables are self-explanatory.

It was impossible, by the method of compaction originally adopted, to produce a state of complete saturation in the specimens. As the program continued, the degree of saturation of the samples was increased. The samples impregnated by electro-osmosis were very nearly saturated. It should be noted that some of the samples had evidences of free water at the time they were introduced to the Frost Action Cabinet, but from later computations, were found to be only about 70% to 90% saturated. The results, however, indicated no definite trend toward any constant value of the product of the viscosity and the rate of heave.

9. Remarks Regarding Particular Test Specimens

Although some of the specimens yielded values of the product of the viscosity and the maximum rate of heave per 1000 degree hours which were within fairly narrow margins, these tendencies were not common to any particular range of viscosities. Samples 9, 10, 11 and 12, having viscosities of 7.5, 4.4, 2.0 and 1.8, yielded values of 6.6, 5.6, 5.0 and 5.6 respectively. However, the succeeding tests had comparative values at the higher range of viscosities, viz, samples 13 and 15, having viscosities of 20.0 and 7.3 respectively, produced a common value of 2.6.

Comparing samples from different sets to one another, some tendencies are shown in the following Tables XIV and XV.

TABLE XIV. MAXIMUM RATE OF HEAVE - EXERPTS FROM TABLE XII

Sample No.	Admixture	Viscosity x Maximum Rate of Heave Per 1000 Degree Hours	Viscosity
5	Lig. BD	15.9	2.0
6	Nil	14.3	1.8
18	Nil	15.5	1.8
25	Aer. MA	12.4	19.6
29	Lig. BD	13.2	2.0
40	Lig. BD	15.0	2.3
48	Lig. BD	12.8	2.3
49	Lig. BD	12.5	3.6
50	Lig. BD	13.8	5.6
3	Lig. BD	21.5	10.1
7	Lig. XD	19.0	25.0
28	Aer. TEF	18.7	10.2
31	Nil	17.9	1.8
32	Lig. BD	20.4	5.0
41	Lig. BD	18.1	5.0
42	Nil	22.5	1.8
8	Lig. XD	9.1	14.1
34	Calgon	8.2	5.9
45	Aer. No.22	8.5	20.6
13	Lig. XD	2.6	20.0
15	Lig. XD	2.6	7.3
16	Lig. XD	1.0	5.0
35	Sugar Beet Molasses	3.2	3.0
38	Lig. BD	2.5	5.6
39	Lig. BD	2.6	3.6
46	Aer. No.22	1.4	2.5

Some conclusions can be drawn from Tables XIV and XV:

1. There is a wide range of values to be compared.

2. The values fall within three or four limiting margins.

3. Since the data must be accepted or rejected as a whole,

unless valid reasons be presented for the rejection of part of it, the conclusion which must be drawn from Table XIV is that no correlation has been found between the viscosity and the rate of heave.

Table XV assembles the samples into one group, from the Average Rate of Heave Table.

TABLE XV. AVERAGE RATE OF HEAVE - EXERPTS FROM TABLE XIII

Sample No.	Admixture	Viscosity x Average Rate of Heave Per 1000 Degree Hours		Viscosity
		Not Considering Expansion	Considering Expansion	
4	Lig. BD	6.6	5.4	5.0
5	Lig. BD	3.7	3.4	2.0
6	Nil	3.9	3.7	1.8
8	Lig. XD	7.5	6.3	14.1
9	Lig. XD	5.0	4.3	7.5
10	Lig. XD	4.0	3.4	4.4
11	Lig. XD	3.5	2.9	2.0
12	Nil	4.7	3.2	1.8
17	Lig. XD	6.3	5.6	2.0
28	Aer. TEF	7.8	2.5	10.2
31	Nil	5.1	4.8	1.8
32	Lig. BD	9.0	4.8	5.0
34	Calgon	2.6	1.6	5.9
35	Sugar Beet Molasses	1.2	0.5	3.0
38	Lig. BD	3.0	---	5.6
39	Lig. BD	2.6	---	3.6
40	Lig. BD	5.0	3.4	2.3
41	Lig. BD	3.5	2.3	2.0
45	Aer. No.22	3.9	2.3	2.3
48	Lig. BD	2.0	---	2.3
49	Lig. BD	2.4	---	3.6
50	Lig. BD	4.1	---	5.6

Again, the same conclusions are appropriate, and they have merely been stressed further.

Samples 55 to 60 were tested with Lignosol BD solutions of 0, 1, 2, 4, 6 and 10%. Solutions of these strengths have viscosities between 1.8 (water)

and 2.4 (10% sol'n). The object was to see if the treated soils would act similarly to one another under freezing conditions, since the viscosities of the saturating fluids were very nearly equal. The tests, however, proved conclusively that the viscosity was not the controlling factor, and indeed was seemingly a very minor one. The curves show that the rate of heaving is a function of the amount of Lignosol added to the soil. The indication is that some action of the admixture on the soil is proportional to the amount added.

The sodium-carbonate-treated samples did not bear out the argument presented earlier. The reverse of the expected heaving occurred, with a greater amount of heaving corresponding to a greater concentration of the admixture. The heaving did not follow any tendency to vary with the dry densities nor the initial degree of saturation of the specimens. Furthermore, the viscosities of solutions of this admixture, as with all the others, varies directly with the solution strength.

The Lignosol layer in Sample 54 did not reduce the heaving to the same extent as the totally treated Sample 39, which had the same solution strength of the admixture. However, the heaving was reduced to approximately one-third that of the untreated sample.

Until the depth of frost penetration reached the treated layer, the formation of ice lenses would be restricted by the action of the Lignosol. When the frost line passed through the layer, and the ice lenses were being formed below it, the sample would act like an untreated sample. The frost penetration would be more rapid in Sample 54 than in the untreated sample, due to the limited heat transfer in the zone of freezing, caused by the restraint on the upward flow of water.

and 8.1 [illegible]. The [illegible] was [illegible] at the [illegible] point [illegible] of [illegible] under [illegible] conditions, since the [illegible] of the [illegible] were very nearly equal. The [illegible], however, [illegible] that the [illegible] was not the controlling factor, and [illegible] was [illegible] a very [illegible]. The [illegible] that the [illegible] of [illegible] a function of the [illegible] of [illegible] added to the soil. The [illegible] is that some [illegible] of the [illegible] on the soil is [illegible] to the [illegible] added.

The [illegible]-lignosulfonate [illegible] [illegible] the [illegible] [illegible]. The [illegible] of the [illegible], with a greater [illegible] in [illegible] to a [illegible] of the [illegible]. The [illegible] and the [illegible] [illegible] and the [illegible] of [illegible] of the [illegible]. [illegible] the [illegible] of [illegible] of [illegible], [illegible] directly with the [illegible].

The lignosulfonate [illegible] [illegible] the [illegible] amount as the [illegible] [illegible], [illegible] strength of the [illegible]. [illegible], the [illegible] the [illegible] of the [illegible].

Until the [illegible] [illegible] the [illegible] [illegible] of the [illegible] [illegible] when the [illegible] through the [illegible] and [illegible] [illegible] the [illegible]. The [illegible] [illegible] to the [illegible] [illegible] to the [illegible] [illegible].

The insulation used was selected to minimize the transfer of water from the specimens to it. There was, however, enough fine material present to draw the water from the samples, as evidenced by a frost line about one inch above the top of the sample board. This was noticed in the later stages of the freezing period only. At first indications of this occurrence, the insulation was agitated in the areas adjacent to the samples to reduce the soil-water transfer.

Lignosol and Aerosol reduce surface tension. Since the rate of capillary rise is dependent on the surface tension, then the rate of the formation of ice lenses should also be a function of the surface tension.

10. Tension Table Tests

Since the differences in the viscosities of the admixtures have not been shown to be the major factor involved in the prevention of ice segregation, a late test was carried out to determine the effects of the admixtures on surface tension.

The test was essentially the application of a certain tension on the liquid phase of a saturated sample of soil. One sample was saturated with water, the other with a 3% solution of Lignosol BD, by filling a pan with the solution and immersing, but not submerging, the sample plus mold in it. The sample was saturated from bottom to top, thus releasing any entrapped air, and was ready for testing.

The Tension Table consisted of a rectangular pan covered with a thick glass plate, and having a 1-inch lip around the perimeter; a 1/4-inch hole was drilled through the two at the centre of the tray, from which a rubber tube hung. Over the glass tray were placed a screen (window-type) and a large blotter covering most of the tray. The tray was filled with water and allowed

to drain through the tube. The distance from the surface of the tray to the bottom of the tube was set at 60 cm. When all the water had drained from the tray, a column of 60 cm. of water was suspended in the tube by the capillary pull of the water in the blotter. This distance was therefore a function of the pore spaces of the blotter, a greater height of water being more than the blotter could support.

The saturated samples then were placed on the surface of the blotter. This contact destroyed the surface tension at the face of the blotter and transferred it to the fluid in the specimen. The weights of the specimens were determined after the test, and having made them up with exact amounts of dry soil, the retained amount of liquid was computed.

A solution strength of 3% Lignosol has a viscosity inappreciably different from that of water and therefore the tension necessary to draw the liquids out of the samples was independent of the viscosity but solely dependent on

1. The smallest pore space in the sample;
2. The surface tension of the fluid;
3. The angle of contact of the fluid and the soil particles.

Since the soil for each sample was the same and treated in an identical manner, the first item was considered to be the same for the two samples.

The moisture retained then, after the tension had been applied, was dependent on the last two factors, but since the problem's answer as a whole was the necessary information, these last two factors were not separated.

TABLE XVI. TENSION TABLE TESTS

Soil used = 484.0 gms.

After Test

Saturating Fluid	Water	% Lig. XD
T + W + S	757.0	743.0
T + S	648.6	649.8
T	164.6 (A34)	165.6 (ABI)
S	484.0	484.2
W	108.4	93.2

The surface tension has been reduced considerably.

It is clear from the tests that the surface tension of water (and/or the angle of contact) is reduced by the addition of Lignosol. Since this is true, then another factor with respect to the reduction of ice segregation is undoubtedly the partial destruction of the capillary pull of the upward-percolating fluid in a freezing soil. Briefly, with the surface tension reduced, the rate of migration of water from the water table to the zone of freezing would be reduced, thus reducing the heaving of the soil.

The soil used was screened Elk Island sand, passing the No. 50 sieve.

11. Soil Types At Sites

Spruce Grove:

Fairly coarse sand and gravel mixture, with a high percentage of fines. This soil would be classified as being quite susceptible to ice segregation. The eastern area had a small percentage of sand sizes with the body being in the silt range and containing 25% clay. The heaving was more pronounced in the silty area.

Stony Plain:

Silty clay with 25% to 35% clay sizes. Fairly susceptible to frost action.

Fallis:

Sandy silt with about 5% clay sizes. Ideal for the formation of ice lenses.

Conditions:-

Spruce Grove:

Water table at 8' depth. Site chosen at a 7' to 8' cut.

Stony Plain:

Water table at 8' depth. Drainage conditions very poor as indicated by the abundance of surface water covering the area after a thaw.

Fallis:

Water table at 7' depth. Bordered by Lake Wabamun on the south and rising land on the north.

TABLE XVII. SOIL TYPES ENCOUNTERED AT THE THREE TEST SITES

FALLIS

Distance East of Mile 50 Signpost	12.8'	29.8'	43.7'	47.5'
Depth 0 - 3'	Ballast	Ballast	Ballast	Ballast
" 3' - 4'	Fine sand and silt	Fine sand and silt	Fine silty sand. Some clay.	Gravel and sand.
" 4' - 5'	"	"	"	Gravel and sand. Some silt.
" 5' - 6'	As above. Some clay.	As above. Some clay.	As above.	Gravelly sand & silt. Layer of large stones - 6' depth.

The typical grading curve for this soil is shown in Figure 25, referred to as Soil #2.

STONY PLAIN STATION YARDS

Distance from Rail Mark	32.5'	0'	45.7'
Depth 0 - 3'	Gravel and cinder fill.	Gravel and cinder fill.	Gravel and cinder fill.
" 3' - 3.5'	Silty clay (wet).	Silt (very wet).	Light clay.
" 3.5'-6'	Clayey silt	Clayey silt.	Silty clay.

Grading curves for these soils are shown in Figures 24 and 25, referred to as Soils #3 and #4.

SPRUCE GROVE

Distance from Point 0.	0'	19.7' East	49' East
Depth 0 - 2'	Ballast	Ballast	Ballast
" 2' - 3'	Silt (wet).	Sandy clay.	Topsoil.
" 3' - 6'	Coarse sand and gravel.	Sandy clay.	Light clay and sand.

Grading curves for these soils are shown in Figure 24, referred to as Soil #1.

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GRAIN SIZE CURVE

PROJECT	
SITE	
SAMPLE	
LOCATION	
HOLE	DEPTH
TECHNICIAN	DATE

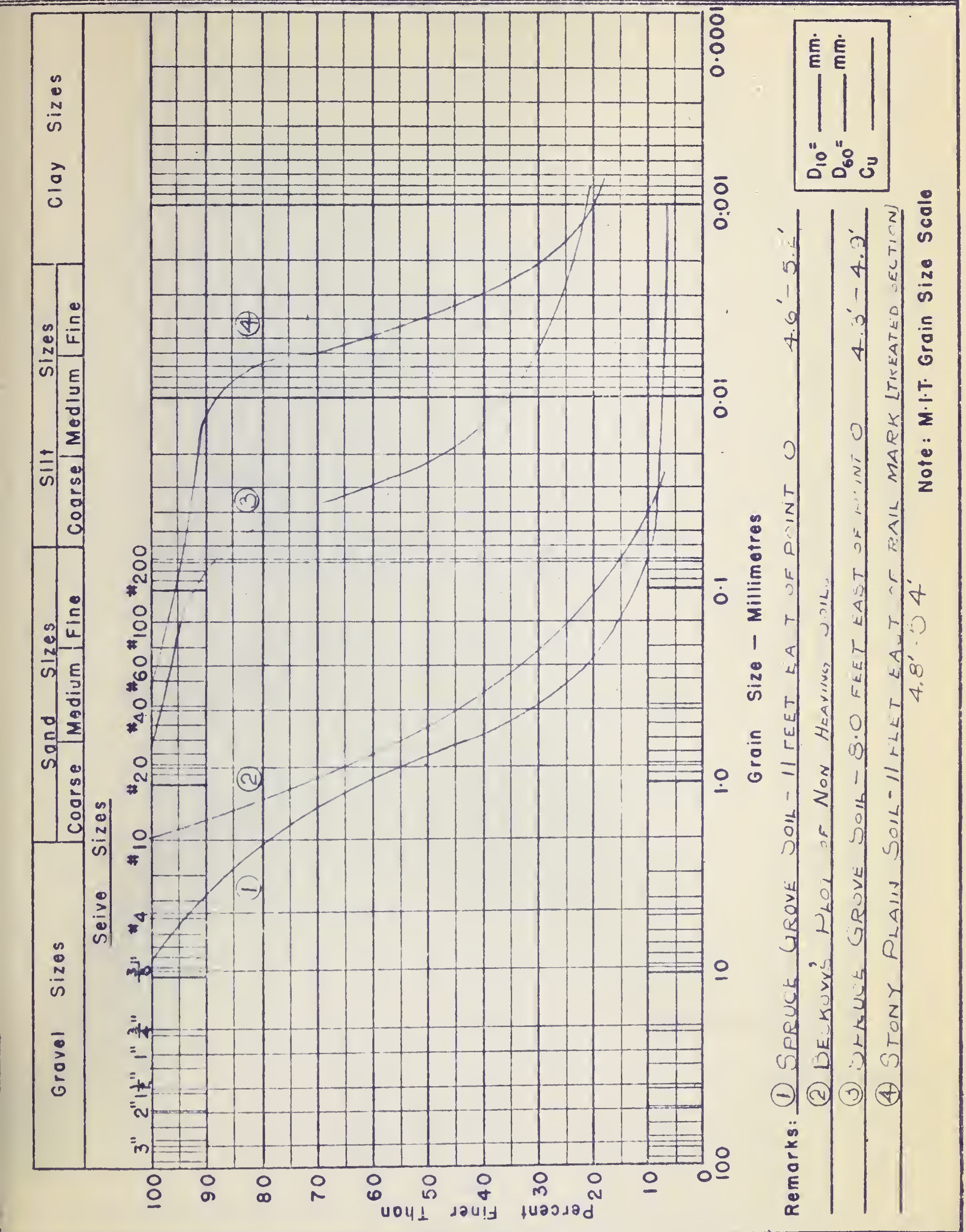
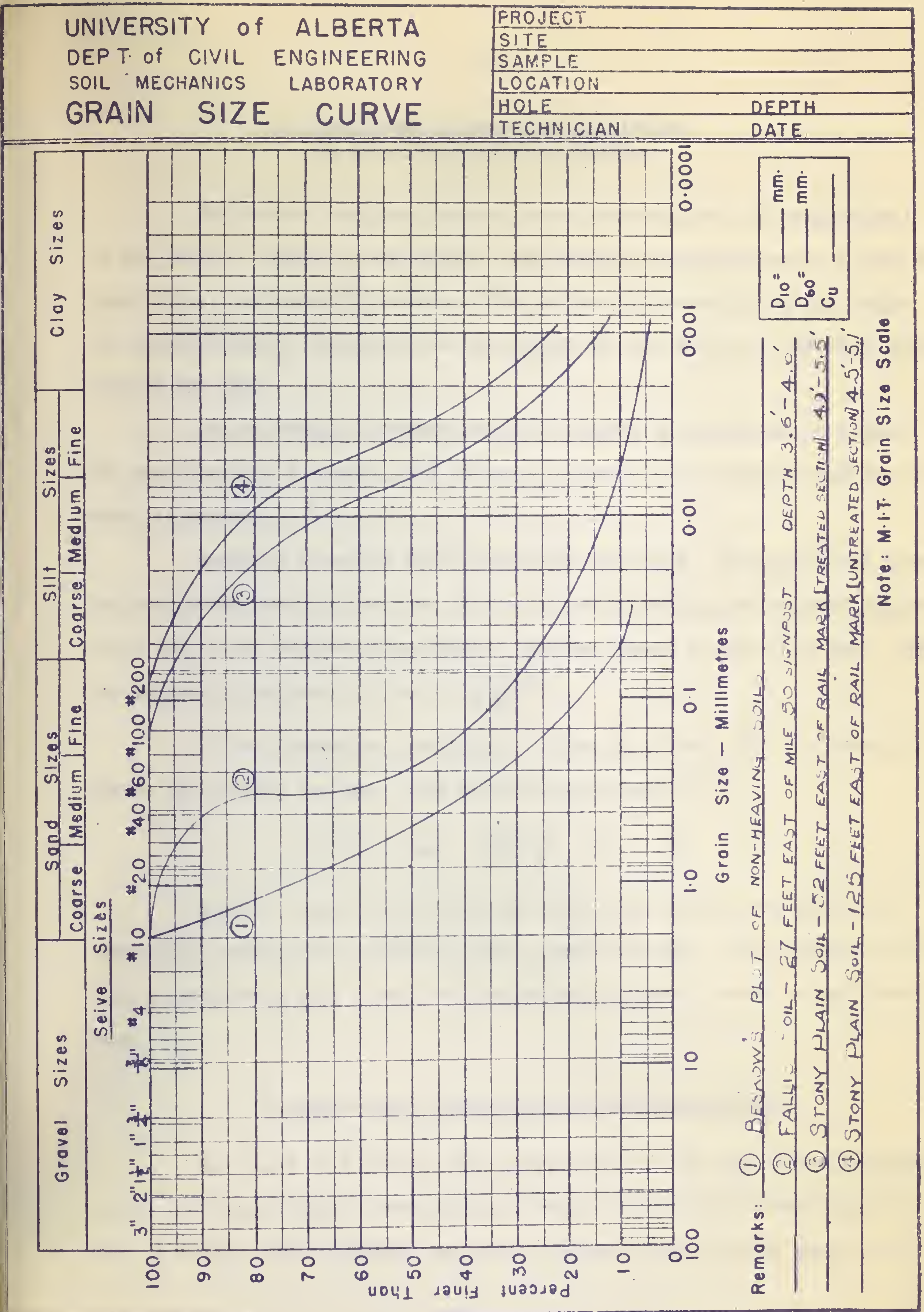


Fig. 24.



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GRAIN SIZE CURVE
PROJECT
SITE
SAMPLE
LOCATION
HOLE
DEPTH
TECHNICIAN
DATE
Gravel Sizes
Sand Sizes
Coarse
Medium
Fine
Silt Sizes
Coarse
Medium
Fine
Clay Sizes
Seive Sizes
3" 2" 1½" 1" ¾" ⅜" #4 #10 #20 #40 #60 #100 #200
Percent Finer Than
100 90 80 70 60 50 40 30 20 10 0
100 10 1·0 0·1 0·01 0·001 0·0001
Grain Size — Millimetres
D10 = mm.
D60 = mm.
Cu
Remarks:
① BESKOW'S PLOT OF NON-HEAVING SOILS
② FALLIS SOIL - 27 FEET EAST OF MILE 50 SIGNPOST DEPTH 3.6'-4.6'
③ STONY PLAIN SOIL - 52 FEET EAST OF RAIL MARK [TREATED SECTION] 4.5'-5.5'
④ STONY PLAIN SOIL - 125 FEET EAST OF RAIL MARK [UNTREATED SECTION] 4.5'-5.5'
Note: M·I·T· Grain Size Scale

Fig. 25.

12. Comparison of Laboratory Conditions to Field Conditions for Heaving

The rate of capillary rise of water through a soil is proportional to the surface tension of the liquid. The higher the water rises in a soil by capillarity, the slower it travels. The restraining force (being the height of capillary water) increases with the height of rise while the capillary force remains the same.

One hypothesis contends that the affinity of a growing ice crystal for water creates a suction, and therefore another force promoting the rise of water is produced.

Consider a case of frost heaving in the field. Let the forces drawing the ground water to the zone of freezing be P_1 and P_2, due to the capillary force and to the suction respectively. Let the height of rise be H feet. Then the hydraulic gradient is $i_F = \dfrac{P_1 + P_2}{H \gamma_W}$

In the laboratory, the height of rise is h feet. The two actuating forces will remain the same. The hydraulic gradient will be

$$i_{Lab} = \frac{P_1 + P_2}{h \gamma_W} > i_F$$

Briefly, then, the restraining forces vary between the field and laboratory, whereas the actuating forces remain the same. The indication is that a non-heaving soil in the field might well produce a heave in the laboratory.

13. Field Heave Predictions from Laboratory Tests

The heave of a soil is very nearly equal to the sum of the thicknesses of the ice lenses formed. Therefore the factor "q" in Darcy's Law (the rate of flow of water) also represents the rate of heave. Then: Rate of Heave = kiA.

At Stony Plain and Spruce Grove, the water table is about 8 feet below the ground surface. Consider the field and laboratory soils to have equal permeabilities. Consider a unit area in each case. Since the actuating forces are equal in each case, then the respective hydraulic gradients, if a value of 1 is assigned to the laboratory sample (having a mean height of rise of 3"), are 1 and 1/24. The value of 1/24 is arrived at by considering a frost penetration of 4 feet. Since the hydraulic gradient increases as the frost line goes down, a "mean frost line" at a depth of 2 feet was considered. Then the mean distance of travel from the free water surface to the freezing zone is 6 feet, and the hydraulic gradient is 1/24.

Since no samples from the test sites were obtained this year, an analysis was made using Yurkiw's data. The deduced rates of heave are found from lab. rate / 24. The lab. rate was determined from examination of lab. data and the picking out of the general tendency toward constant conditions.

TABLE XVIII. DEDUCED FIELD RATE OF HEAVE - SPRUCE GROVE

	FIELD			LAB.		
	Day to Day	Elapsed	Rate of Heave 11'E	Sample	Rate of Heave	Deduced Field Rate of Heave
1	Dec.27/51 to Jan.26/52	30 days	0.00067'/day	33	0.0083'/day	0.00035'/day
2	Dec.27/51 to Mar.15/52	78 days	0.00078'/day	34	0.0083'/day	0.00035'/day

(33)- 8'E of "0" Rail (34)- 11'E of "0" Rail
Both from between 4' and 5' depths.

Now consider the heaving at some other arbitrarily-chosen point, i.e. at 30'E of "0" Rail:

Dec.27/51) to) Jan.26/52)	30 days	0.005'/day
Dec.27/51) to) Mar.15/52)	78 days	0.0029'/day

These samples have some trend towards a correlation with the field but only in the immediate vicinity of the area from which they were obtained.

TABLE XIX. DEDUCED FIELD RATE OF HEAVE - STONY PLAIN

FIELD			LAB.		
Day to Day	Elapsed	Rate of Heave 88'E	Sample	Rate of Heave	Deduced Field Rate of Heave
Dec.27/51) to) Jan.26/52)	30 days	0.0021'/day	31	0.0042'/day	0.00018'/day
Dec.27/51) to) Apr. 5/52)	99 days	0.0013'/day	39	0.0208'/day	0.0009'/day
			41	0.0125'/day	0.0005'/day

Note: Sample 31 untreated. (125'E of "0" Rail)
Samples 39 and 41 leached. (39)- 11'E of "0" Rail. (41)- 52'E of "0" Rail
Field heaves at point 88'E of "0" Rail. Nearest injection hole 11'W and none to the East.

These few trial computations warrant further investigation.

TABLE XX. DEDUCED FIELD RATE OF HEAVE - FALLIS

LAB.

Sample No.	Rate of Heave	Deduced Field Rate of Heave
23	0.0334 ft./day	0.00139 ft./day
24	0.0292 ft./day	0.00122 ft./day

Note: Sample 23 - 27' E. of Mile 50 Signpost: 3 1/2 ft. to 4 ft.
Sample 24 - 27' E. of Mile 50 Signpost: 4 ft. to 4 1/2 ft.

FIELD

(Rate of Heave in Ft./Day)

		North Side of Tracks			South Side of Tracks		
Day to Day	Elapsed	1'E	27'E	38.5'E	1'E	27'E	38.5'E
Nov.10/52) to) Jan.17/53)	68 days	0.00059	0.00191	0.00162	0.00044	0.00147	0.00088
Nov.10/52) to) Feb.10/53)	92 days	0.00076	0.00196	0.00185	0.00054	0.00131	0.00120
Nov.10/52) to) Mar.16/53)	126 days	0.00048	0.00135	0.00119	0.00024	0.00096	0.00103
Jan.17/53) to) Feb.10/53)	24 days	0.00125	0.00208	0.00250	0.00083	0.00083	0.00208
Jan.17/53) to) Mar.16/53)	58 days	0.00034	0.00068	0.00068	0.00000	0.00034	0.00121
Feb.10/53) to) Mar.16/53)	34 days	0.00000	0.00000	0.00000	0.00000	0.00000	0.00061

TABLE XXI. DEDUCED FIELD RATE OF HEAVE - STONY PLAIN

(Rate of Heave in Ft./Day)

		North Side of Tracks			South Side of Tracks		
Day to Day	Elapsed	10'E	49'E	88'E	10'E	49'E	88'E
Jan. 6/51) to) Feb. 1/51)	26 days	0.00231	0.00460	0.00150	0.00231	0.00500	0.00231
Jan. 6/51) to) Apr. 5/51)	89 days	0.00191	0.00290	0.00110	0.00202	0.00348	0.00169
Feb. 1/51) to) Apr. 5/51)	63 days	0.00175	0.00221	0.00095	0.00191	0.00286	0.00143
Jan. 26/52) to) Feb. 15/52)	20 days	0.00350	0.00350	0.00200	0.00400	0.00400	0.00000
Jan.26/52) to) Apr. 5/52)	69 days	0.00145	0.00150	0.00100	0.00145	0.00188	0.00130
Feb.15/52) to) Apr. 5/52)	49 days	0.00060	0.00060	0.00060	0.00040	0.00102	0.00184
Jan.17/53) to) Feb. 3/53)	17 days	0.00000	0.00590	0.00180	0.00180	0.00940	0.00350
Jan. 17/53) to) Mar. 16/53)	58 days	0.00017	0.00260	0.00090	0.00155	0.00397	0.00121
Feb. 3/53) to) Mar.16/53)	41 days	0.00024	0.00120	0.00050	0.00171	0.00171	0.00024

Deduced field rates of heave from Table XIX:

125' E = 0.00018 ft./day.
52' E = 0.0009 ft./day.
11' E = 0.0005 ft./day.

TABLE XXII. DEDUCED FIELD RATE OF HEAVE - SPRUCE GROVE

(Rate of Heave in Ft./Day)

Day to Day	Elapsed	North Side of Track Only 9.5'E	34.5'E	49'E
Dec. 7/50) to) Apr. 5/51)	119 days	0.00025	0.00084	0.00075
Jan.26/52) to) Apr. 5/52)	69 days	0.00058	0.00101	0.00131
Jan.17/53) to) Feb. 3/53)	17 days	0.00000	0.00294	0.00117
Jan.17/53) to) Mar.16/53)	58 days	0.00034	0.00138	0.00086
Feb. 3/53) to) Mar.16/53)	41 days	0.00049	0.00073	0.00073

At the location where the test samples were obtained, the rates of heave for the three years, at different periods in the years, vary from 25×10^{-5}ft./day to 58×10^{-5}ft./day. The deduced field rate of heave from the laboratory data is 35×10^{-5}ft./day. This is a very unreliable value when it is realized that other factors affecting heaving have not been assessed because of their intangibility. Such things as the rate of frost penetration, variation in ground water level, stratification of the soil at the field sites, fluctuation of the temperature, variable insulation due to the thickness and nature of the soil overburden, snow and ice, etc., all enter the mechanics of heaving. A change in the ground water elevation plus

a change in the frost penetration will in effect contribute jointly to a change in the height of capillary rise of the ground water to the zone of freezing. This case will be discussed. A different height of capillary rise in the laboratory samples, along with the aforementioned factor, will change the relative hydraulic gradients of the field and laboratory.

The field rates of heave at point 9.5 ft. E. are reviewed in Table XXIII. The rates of heave represent the amount of heaving which would take place in any one day if the total heave were uniformly distributed over the period under consideration. The levels were measured to 0.01 ft. If an error of measurement of 0.01 ft. is considered (introducing an error of 0.02' in the computed heave), the rates of heave would change considerably since the maximum heave in any of the periods at this point was 0.04 ft. Then, whereas a heave of 0.03 ft. in 119 days (Dec. 7/50 to Apr. 5/51) yielded a rate of 25 x 10^{-5}ft./day, a heave of 0.01 ft. would represent 8.3 x 10^{-5}ft/day, and a heave of 0.05 ft. would represent 42 x 10^{-5}ft./day. The rates in all the periods are treated this way in the following table.

TABLE XXIII. POSSIBLE ERRORS AT LEVEL POINT 9.5 FT. E.

Period	Heave (ft.)	Possible Error (ft.)	Elapsed	Ranges of Rates of Heave x 10^{-5}
Dec. 7/50 to Apr. 5/51	0.03	0.02	119	8 to 32
Jan. 26/52 to Apr. 5/52	0.04	0.02	69	29 to 97
Jan. 17/53 to Feb. 3/53	0.00	0.02	17	0 to 118
Jan. 17/53 to Mar. 16/53	0.02	0.02	58	0 to 69
Feb. 3/53 to Mar. 16/53	0.04	0.02	41	49 to 147

The range is now widened to (8 to 147) x 10^{-5}ft./day. Although seemingly very widely spread, it must be kept in mind that this is only a

variation of 0.00139 ft./day, about 0.02 in./day.

The laboratory rate might well be 100% in error using the method herein described, yet even as a rough estimate it does reveal that it yields a deduced field rate of heave of the same order of magnitude as the actual field rates. It was stated that the deduced field rate was 35×10^{-5} ft./day, based on a lab. rate of 0.0083 ft./day. However, the lab rate varies from 0.0017 to 0.0332 ft./day, which in turn would change the deduced rate from 35×10^{-5} to some value in the range 7×10^{-5} to 138×10^{-5}.

Now with this range of deducible field rates of heave, a correction for the ratio of the field and lab. hydraulic gradients may be made. Until now, all computations have been made considering mean capillary rises of 3" in the lab. and 6' in the field, with the ratio of the hydraulic gradients of 1:24. Consider the mean capillary height in the lab. to have a range of 5" to 1" and in the field 2' to 8'. Then $4.8 < i\ (\text{field})/i\ (\text{lab.}) \leq 96$. The range of 7×10^{-5} to 138×10^{-5} would be widened to 1.8×10^{-5} to 691×10^{-5}. Of course, some of these errors might be compensating, but the general picture is that with the available data, the problem cannot be solved. The indication is that there could be a representative correlation if these margins of possible error were reduced.

This treatment of the Stony Plain and Fallis areas would give the same conclusions.

14. Permeabilities from Consolidation Tests

If the flow of water through a soil of given dry density is retarded by the viscous action of an admixture, then the permeability of the soil with respect to the flow of water through it may be said to have been changed. That is, whereas in previous discussion the permeabilities of the soils were considered equal but the percolating fluid was considered to change in character, the reverse procedure will now be discussed. Let the assumption be that water is the percolating fluid in all cases, and that the admixtures change the permeability of the soil. Then by finding the permeabilities of a soil, with different admixtures added and with no admixtures added, with all other factors being considered constant, the hypothesis that the viscosity of the admixture is directly proportional to its rate of flow through the soil may be further analyzed.

The data used was taken from an associated program by Yurkiw, but the soil used for the consolidation tests was not the same as that used for the freezing tests.

The coefficient of permeability of a soil may be computed from consolidation test data, using the following equation:

$$k = \frac{T \, a_v \, H^2 \gamma_w}{t \, (1 + e)} \quad , \text{ where}$$

T = time factor taken from the theoretical time curve for the same percent consolidation corresponding to an arbitrarily selected time "t" on the experimental curve.

a_v = coefficient of compressibility = average slope of the pressure-void ratio curve over the range of the load increment for the time curve being considered.

e = average void ratio for the load increment.

H = the height of specimen corresponding to e, when drained on one side.

The coefficient of permeability is usually most conveniently computed for the time "t" corresponding to 50% consolidation. For this case the time factor is equal to 0.2.

It is obvious, then, that the coefficient of permeability will be different for each load applied to the specimen, since the void ratio will change.

To illustrate the method of determining "t", the time for 50% consolidation to occur, Casagrande's method is shown for the consolidation test on the non-treated sample.

The essence of the method is to determine 0% consolidation and 100% consolidation, and at the dial reading midway between them, to pick off the corresponding time.

0% is found by determining the axis to which the upper part of the "time curve" would be related as a parabola. This is an approximation, of course, since the curve is not actually parabolic. The approximate axis of 0% consolidation is found by plotting a point above "t", an amount equal to the dial reading difference on the curve between t and 4t. For instance, on the 20 gm. time curve at t = 4 minutes, dial reading = 9108. At t = 1 minute, dial reading = 9114. The difference in dial readings of 6 is plotted above 9114 at t = 1 minute. A series of points such as this approximates a straight line which is called the 0% consolidation line.

100% consolidation is determined by extending the straight line portion of the time curve to intersect the extension of the secondary time branch tangent.

Consider two specimens, one treated and the other untreated, each having the same e value in the expression for k. Let k_1 and k_2 be the values of the coefficients of permeability for the treated and untreated samples respectively, as computed from the consolidation tests.

$$\frac{k_1}{k_2} = \frac{\nu_2}{\nu_1}$$

Therefore $k_1 \nu_1 = k_2 \nu_2$.

Consolidation tests were conducted on a soil with a grain size distribution shown on Fig. 28. The admixtures were added as a percentage of the dry weight of soil and their solution strengths computed from the final moisture content.

The analysis then was to reduce the permeabilities exhibited by the treated samples to the values which they would have had without the admixtures, by multiplying them by the viscosity of the admixture solution. Since the tests were run at room temperature, the viscosity of the water was considered as 1.000 .

Since the soils were all remolded, it seems reasonable that in the range of pressures exceeding the precompression pressures, at any particular pressure, the void ratios should be the same in all the samples.

The permeabilities of the treated samples, being functions of the time, would vary with the resistance to flow offered by the admixtures. This resistance is directly attributable to the viscosity of the fluid, and therefore by correcting the time (by dividing it by the viscosity of the fluid), the corrected permeability of the soil may be compared to that of the permeability of an untreated sample, at the same pressure.

The basis for this method of comparison is that the e values may

CONSOLIDATION TESTS SUMMARY SHEET

LOAD	ADMIXTURE	NIL 1	NIL 2	LIGNOSOL XD	LIGNOSOL BD 1	LIGNOSOL BD 2	SUGAR BEET MOLASSES	CALGON	AEROSOL 0.8	AEROSOL 1B	AEROSOL MA	AEROSOL AY	AEROSOL TEF 16
	INITIAL M.C.	27.0	36.9	27.5	34.4	31.3	31.7	30.4	32.7	32.8	31.4	28.4	2[illegible].5
	FINAL M.C.	15.9	16.4	20.4	15.8	16.0	16.9	18.6	16.1	16.2	16.2	15.9	13.9
	IN. DRY DENS.												
	INITIAL e	0.823	1.084	0.768	0.946	0.877	0.898	0.845	0.961	0.921	0.931	0.883	0.799
	FINAL e	0.410	0.424	0.526	0.407	0.413	0.436	0.480	0.416	0.418	0.416	0.410	[illegible]
20	BRG. PRESS.	0.070	0.070										
	e		1.074										
	t_{50} (min.)		20										
	k		2.97×10^{-5}										
	CORR. k		2.97×10^{-5}										
50	BRG. PRESS.	0.158	0.158		0.158				0.158		0.158	0.158	0.158
	e	0.618	1.036		0.897				0.925		0.903	0.869	0.787
	t_{50} (min.)	19	70		320				110		210	1650	45
	k	8.52×10^{-6}	1.82×10^{-5}		3.25×10^{-6}				3.65×10^{-6}		1.78×10^{-6}	1.62×10^{-7}	5.90×10^{-6}
	CORR. k	8.52×10^{-6}	1.82×10^{-5}		5.20×10^{-5}				5.18×10^{-6}		4.73×10^{-6}	3.20×10^{-7}	1.47×10^{-5}
100	BRG. PRESS.	0.304	0.304		0.304			0.304	0.304	0.304	0.304	0.304	0.304
	e		0.983		0.853			0.839	0.891	0.868	0.871	0.841	0.763
	t_{50} (min.)		15		150			82	125	270	90	90	23
	k		4.60×10^{-5}		4.70×10^{-6}			2.56×10^{-6}	2.48×10^{-6}	1.17×10^{-6}	$3.[illegible]\times10^{-6}$	3.26×10^{-6}	1.41×10^{-5}
	CORR. k		4.60×10^{-5}		7.52×10^{-5}			4.10×10^{-6}	3.52×10^{-6}	1.82×10^{-6}	9.30×10^{-6}	6.10×10^{-6}	3.52×10^{-5}
200	BRG. PRESS.	0.596	0.596	0.596	0.596	0.596	0.596	0.596	0.596	0.596	0.596	0.596	0.596
	e	0.750	0.913	0.683	0.796	0.779	0.840	0.814	0.831	0.821	0.814	0.798	0.723
	t_{50} (min.)	32	23	240	78	85	105	165	125	33	34	34	2[illegible]
	k	3.95×10^{-6}	2.54×10^{-5}	7.80×10^{-6}	6.35×10^{-6}	2.72×10^{-6}	4.28×10^{-6}	1.67×10^{-6}	2.51×10^{-6}	7.30×10^{-6}	5.72×10^{-6}	6.16×10^{-6}	$7.2[illegible]\times10^{-5}$
	CORR. k	3.95×10^{-6}	2.54×10^{-5}	1.70×10^{-5}	1.02×10^{-5}	4.62×10^{-6}	4.58×10^{-6}	2.67×10^{-6}	3.56×10^{-6}	1.14×10^{-5}	1.49×10^{-5}	1.15×10^{-5}	1.82×10^{-4}
400	BRG. PRESS.	1.18	1.18	1.18	1.18	1.18	1.18		1.18	1.18	1.18	1.18	1.18
	e	0.702	0.614	0.638	0.724	0.720	0.773		0.750	0.737	0.752	0.745	0.670
	t_{50} (min.)	32	29	61	56	70	185		70	4.2	44	32	6
	k	7.30×10^{-6}	1.15×10^{-5}	1.77×10^{-6}	4.66×10^{-6}	1.91×10^{-6}	1.47×10^{-6}		2.08×10^{-6}	4.79×10^{-5}	2.22×10^{-6}	3.75×10^{-6}	2.10×10^{-5}
	CORR. k	7.30×10^{-6}	1.15×10^{-5}	3.86×10^{-6}	7.46×10^{-5}	3.24×10^{-6}	1.57×10^{-6}		2.96×10^{-6}	7.48×10^{-5}	5.80×10^{-6}	7.02×10^{-6}	5.25×10^{-5}
800	BRG. PRESS.	2.34	2.34	2.34	2.34	2.34	2.34	2.34	2.34	2.34	2.34	2.34	2.34
	e	0.636	0.704	0.589	0.643	0.651	0.676	0.716	0.666	0.658	0.679	0.673	0.609
	t_{50} (min.)	36	17	26	51	38	125	130	57	53	29	31	12
	k	3.65×10^{-6}	9.26×10^{-6}	1.90×10^{-6}	2.68×10^{-6}	1.92×10^{-6}	1.12×10^{-6}	9.61×10^{-7}	1.31×10^{-6}	8.45×10^{-6}	3.01×10^{-6}	2.74×10^{-6}	$5.[illegible]7\times10^{-6}$
	CORR. k	3.65×10^{-6}	9.26×10^{-6}	4.15×10^{-6}	4.29×10^{-5}	3.26×10^{-6}	1.20×10^{-6}	1.54×10^{-6}	1.86×10^{-6}	1.32×10^{-5}	8.04×10^{-6}	5.12×10^{-6}	1.39×10^{-5}
1500	BRG. PRESS.	4.39	4.39	4.39	4.39	4.39	4.39	4.39	4.39	4.39	4.39	4.39	4.39
	e	0.568	0.609	0.549	0.568	0.580	0.609	0.650	0.591	0.590	0.573	0.510	0.530
	t_{50} (min.)	30	17	24	51	65	150	145	44	30	31	28	15
	k	2.13×10^{-6}	3.59×10^{-6}	7.87×10^{-7}	1.07×10^{-6}	5.55×10^{-7}	4.64×10^{-7}	4.75×10^{-7}	6.78×10^{-7}	1.27×10^{-6}	1.27×10^{-6}	3.47×10^{-6}	3.12×10^{-6}
	CORR. k	2.13×10^{-6}	3.59×10^{-6}	1.71×10^{-6}	1.71×10^{-5}	9.42×10^{-7}	4.97×10^{-7}	7.60×10^{-7}	9.62×10^{-7}	1.98×10^{-6}	3.30×10^{-6}	6.50×10^{-6}	7.80×10^{-6}
3000	BRG. PRESS.	8.77	8.77	8.77	8.77	8.77	8.77	8.77	8.77	8.77	8.77	8.17	8.77
	e	0.502	0.530		0.502	0.511	0.537	0.581	0.521	0.519	0.516	0.515	0.460
	t_{50} (min.)	28	14		50	47	150	155	40	41	37	29	15
	k	1.02×10^{-6}	1.99×10^{-6}		5.56×10^{-7}	5.06×10^{-7}	1.92×10^{-7}	2.01×10^{-7}	3.87×10^{-7}	4.38×10^{-7}	4.54×10^{-7}	5.76×10^{-7}	1.15×10^{-6}
	CORR. k	1.02×10^{-6}	1.99×10^{-6}		8.82×10^{-6}	8.60×10^{-7}	2.05×10^{-7}	3.22×10^{-7}	5.50×10^{-7}	6.84×10^{-7}	1.18×10^{-6}	1.08×10^{-6}	2.86×10^{-6}
6000	BRG. PRESS.	17.5	17.5		17.5	17.5	17.5	17.5	17.5	17.5	17.5	17.5	17.5
	e	0.440	0.457		0.437	0.444	0.496	0.513	0.450	0.448	0.447	0.444	0.391
	t_{50} (min.)	29	15		52	54	125	155	42	30	30	40	16
	k	4.20×10^{-7}	8.02×10^{-7}		2.48×10^{-7}	4.61×10^{-7}	1.04×10^{-7}	7.85×10^{-8}	1.59×10^{-7}	2.19×10^{-7}	1.35×10^{-7}	1.32×10^{-7}	5.10×10^{-7}
	CORR. k	4.20×10^{-7}	8.02×10^{-7}		3.48×10^{-6}	7.81×10^{-7}	1.11×10^{-7}	1.50×10^{-7}	2.26×10^{-7}	3.40×10^{-7}	3.51×10^{-7}	3.59×10^{-7}	1.27×10^{-6}
	SOLUTION STRENGTH – %			18.1	14.5	16.0	15.8	16.5	15.3	16.3	15.7	17.6	19.6
	VISCOSITY (ROOM TEMP.)			2.18	1.60	1.70	1.07	1.60	1.42	1.56	2.60	1.87	2.50

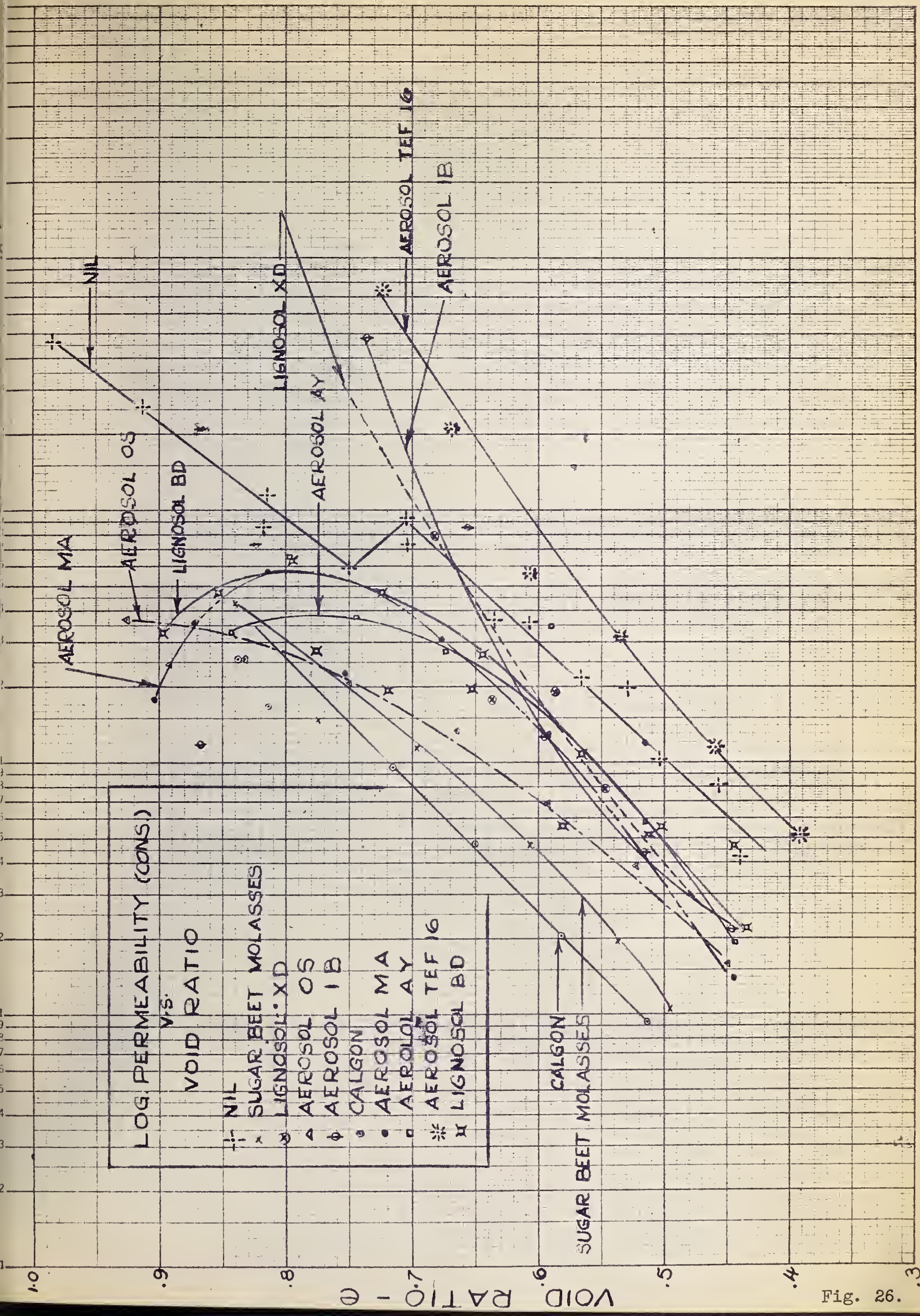

LOG PERMEABILITY (CONS.)
V.S.
VOID RATIO
NIL
SUGAR BEET MOLASSES
LIGNOSOL XD
AEROSOL OS
AEROSOL IB
CALGON
AEROSOL MA
AEROLOL AY
AEROSOL TEF 16
LIGNOSOL BD
AEROSOL MA
AEROSOL OS
LIGNOSOL BD
NIL
AEROSOL AY
LIGNOSOL XD
AEROSOL TEF 16
AEROSOL IB
CALGON
SUGAR BEET MOLASSES
1.0
.9
.8
.7
.6
.5
.4
.3
VOID RATIO - e

Fig. 26.

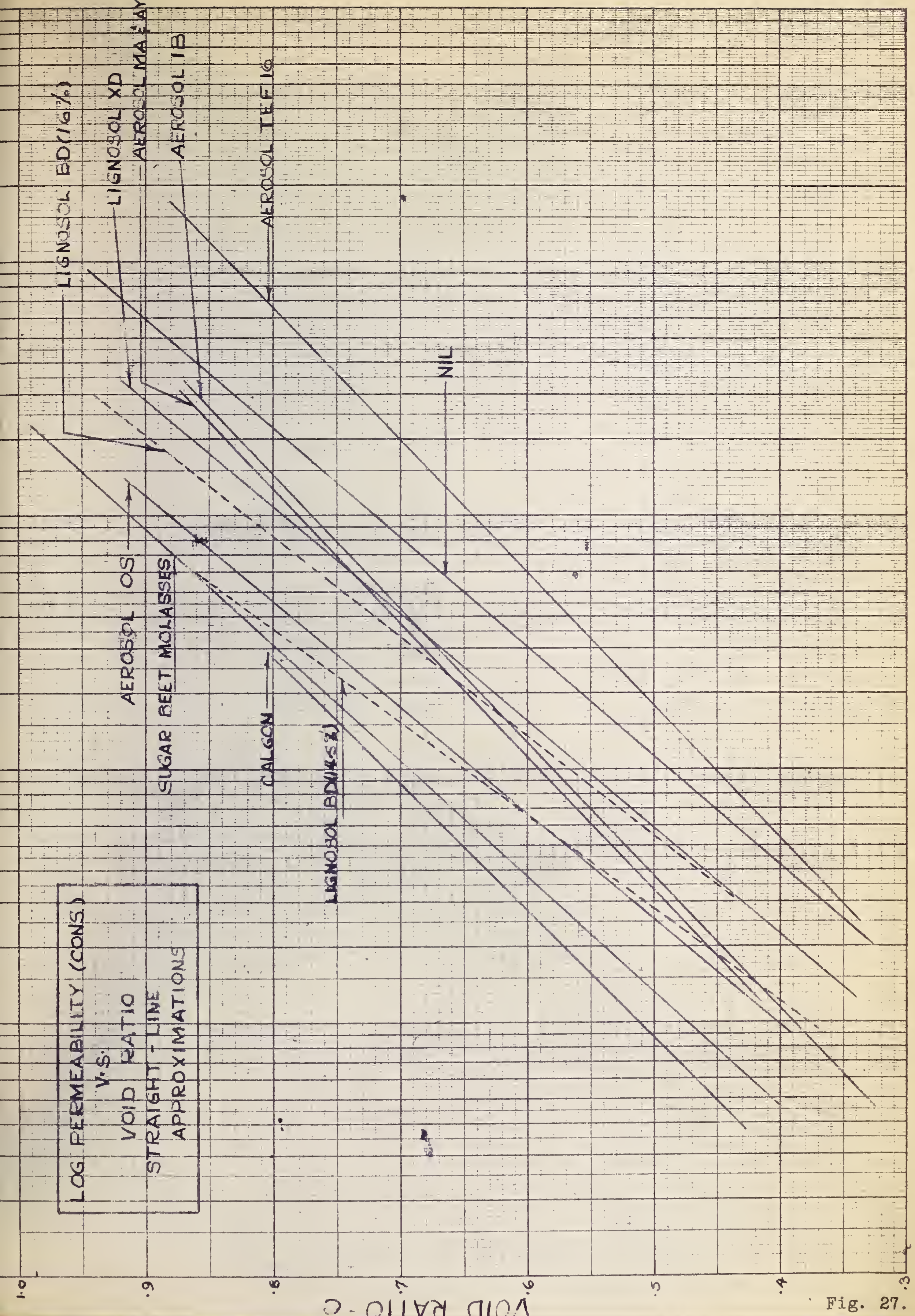

LOG PERMEABILITY (CONS.)
V.S.
VOID RATIO
STRAIGHT - LINE
APPROXIMATIONS
LIGNOSOL BD(16%)
LIGNOSOL XD
AEROSOL MA & AY
AEROSOL IB
AEROSOL TE F 16
NIL
AEROSOL OS
SUGAR BEET MOLASSES
CALGON
LIGNOSOL BD(4.5%)
1.0
.9
.8
.7
.6
.5
.4
.3
VOID RATIO - e

Fig. 27.

UNIVERSITY of ALBERTA
DEPT. of CIVIL ENGINEERING
SOIL MECHANICS LABORATORY

GRAIN SIZE CURVE

PROJECT	
SITE	
SAMPLE	
LOCATION	
HOLE	DEPTH
TECHNICIAN	DATE

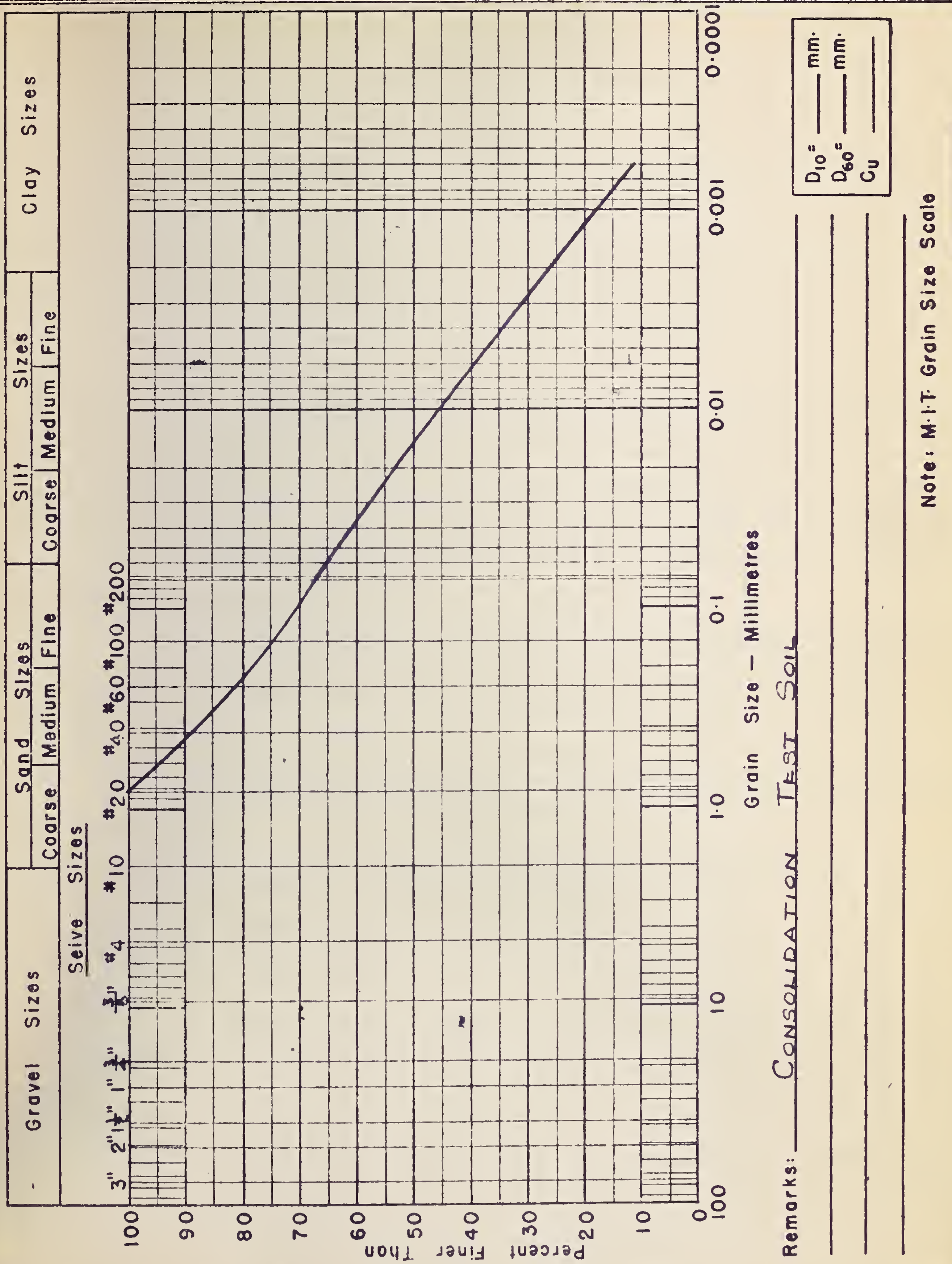
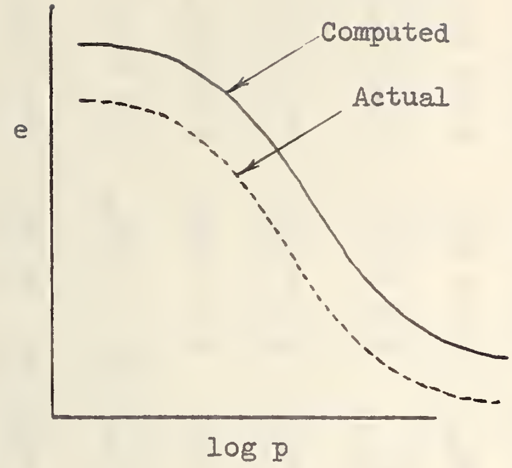


Fig. 28.



not too reliable, being based on the final moisture content of the consolidation specimen, and that the curve of e - log p would be displaced vertically, indicating an incorrect relationship between these two quantities. The computed permeabilities, being dependent on the void ratio and the pressure, would be in error.

From the test data it may be seen that some other effects are produced by the admixtures, which curtail the flow of water through the soils.

The heave curves indicate the order of effectiveness of the admixtures to be:

1. Lignosols BD and XD, Calgon and Sugar Beet Molasses.
2. Aerosols OTB, MA, and No. 22.
3. Aerosol TEF 16.

A summary sheet of the consolidation test results is shown in Table XXIV. From this table, curves of log of the coefficient of permeability vs. void ratio have been plotted for each of the admixtures (Fig. 26). This plot was very erratic in the range of higher void ratios, and a second plot

TABLE XXV. PERMEABILITY REDUCTION ATTRIBUTABLE TO VISCOSITY

Admixture	k $e = 0.9$ (Consol.)	Reduction of k Due to Admixture as Compared to Nil.	k Deduced from k_{nil} i.e. $\frac{k_{nil}}{\nu}$	Percent of Total Reduction Attrib. to Viscosity	k $e = 0.5$ (Consol.)	Reduction of k Due to Admixture as Compared to Nil.	k Deduced from k_{nil} i.e. $\frac{k_{nil}}{\nu}$	Percent of Total Reduction Attrib. to Viscosity
Nil	6.0×10^{-5}				1.1×10^{-6}			
Calgon	8.8×10^{-6}	61.2×10^{-6}	3.75×10^{-5}	37	8.5×10^{-8}	101×10^{-8}	6.9×10^{-7}	4.1
S.B.Mol.	8.8×10^{-6}	61.2×10^{-6}	5.6×10^{-5}	6	1.3×10^{-8}	109×10^{-8}	1.0×10^{-6}	9.2
Lig.XD	2.8×10^{-5}	3.2×10^{-5}	2.76×10^{-5}	100	5.9×10^{-7}	5.1×10^{-7}	5.1×10^{-7}	116
(16%) Lig.BD	2.0×10^{-5}	4.0×10^{-5}	3.53×10^{-5}	61.8	5.4×10^{-7}	5.6×10^{-7}	6.5×10^{-7}	81
(14.5%)Lig.BD	8.0×10^{-6}	62×10^{-6}	3.75×10^{-5}	36	2.8×10^{-7}	8.2×10^{-7}	6.9×10^{-7}	50
Aer.MA	4.9×10^{-5}	1.1×10^{-5}	2.31×10^{-5}	100	3.3×10^{-7}	7.7×10^{-7}	4.2×10^{-7}	88
Aer.AY	4.9×10^{-5}	1.1×10^{-5}	2.62×10^{-5}	100	3.3×10^{-7}	7.7×10^{-7}	5.9×10^{-7}	66
Aer.OS	1.2×10^{-5}	4.8×10^{-5}	4.23×10^{-5}	37	2.5×10^{-7}	8.5×10^{-7}	7.7×10^{-7}	39
Aer.I.B.	5.0×10^{-5}	1.0×10^{-5}	3.84×10^{-5}	100	3.5×10^{-7}	7.3×10^{-7}	7.1×10^{-7}	54

of straight line approximations was made (Fig. 27), from which some conclusions may be drawn, and some characteristics noted.

The straight line approximations fall in the same general slope as the untreated sample's curve.

Aerosol TEF 16 increases the permeability of the soil and should therefore promote heaving.

Table XXV was prepared for the examination of the relationship between heaving, permeability and viscosity. This table, however, showed nothing of a conclusive nature, but led further to the assumption that another factor must be involved. This factor is surface tension.

The amount of reduction of heaving attributable to the viscosity of the saturating fluid has been determined on the basis of the change of permeability of the soil due to the viscous action, as compared to the total permeability change effected by the admixture treatment.

Considering the permeabilities of the soil to be a logarithmic function of the void ratio, best-fit straight lines were drawn through the plotted points from the consolidation data.

At $e = 0.9$, $k_{nil} = 6 \times 10^{-5}$.

$k_{lig.XD} = 2.8 \times 10^{-5}$. (18%)

The heaving rate of the freezing samples should be reduced by about one-half. The viscosities of water and of 18% lig.XD at room temperature are in proportions of 1.00/2.18 or 0.46. The viscosity then is responsible for reducing the permeability from 6×10^{-5} to 2.76×10^{-5}. The percent permeability reduction attributable to the viscosity is 100%.

a straight line approximation was made (Fig. 37). From which some similar curves may be drawn, and some characteristic values.

The straight line approximations fall in the same general slope as the unprocessed sample's curve.

[illegible] may be suggested [illegible] permeability of the soil and should therefore promote heaving.

Table XIX was prepared for an examination of the relationship between heaving, permeability and viscosity. This table, however, showed nothing of a conclusive nature but led further to the assumption that another factor must be involved. This factor is surface tension.

The amount of reduction of heaving attributable to the viscosity of the saturating fluid had been determined on the basis of the change of permeability of the soil due to the viscous coating, as compared to the total permeability change effected by the additive treatment.

Considering the permeability of the soil to be a logarithmic function of the void ratio, best-fit straight lines were drawn through the plotted points from the consolidation tests.

At $e = 0.6$, $k_{[illegible]} = 3 \times 10^{-6}$.

$k_{[illegible]} = 2.6 \times 10^{-6}$. ([illegible])

The heaving rate of the treated samples should be reduced by about one-half. The viscosities of water and of [illegible] at room temperature are in proportions of 1.00/2.11 or 0.48. This therefore would be responsible for reducing the permeability from 3×10^{-6} to 2.6×10^{-6}. The [illegible] permeability reduction attributable to the viscosity is [illegible].

CONCLUSIONS

1. The viscosity of the saturating fluid is a contributing factor, but not the only factor, in the reduction of frost heaving of soils.

2. Sodium carbonate reduces heaving, some particular amount being most effective. When a greater or lesser amount is used, the effectiveness is partially lost. It is important to note that the higher strength solutions of sodium carbonate are more viscous than lower strength solutions, as with all the other admixtures. In effect, then, a greater heave occurred in a sample treated with the more viscous solution. This is in direct disagreement with the original hypothesis.

3. A correlation between laboratory tests and field behavior exists, but prediction of field heaves from analyses of the relating conditions between the laboratory and field is not yet possible, due to a number of relating variables which have not yet been definitely determined.

4. Yurkiw (11) states that Aerosol was detrimental to the prevention of ice segregation in freezing soils. This was an erroneous conclusion, based on insufficient data. The particular Aerosol product used probably had an ingredient foreign to the Aerosol itself which caused the effect. It was a Canadian insecticide having the trade name of "Aer-a-sol".

5. All Aerosols tested in this program reduced the heaving proportionally to the amount of the admixture added. Aerosols OTB, MA, and No. 22 are more effective than Aerosol TEF, but the Lignosols, Calgon, and Sugar Beet Molasses are superior to any of the Aerosols.

6. Lignosols BD and XD, Calgon and Sugar Beet Molasses all have about the same reducing effect on heaving.

7. The reduction of heaving attributable to the viscosity of the saturating fluid is in some cases a very small portion of the total reduction. In other cases, the total reduction may be attributed to the viscosity. There are no linking factors to reveal any distinct trend, and therefore no conclusions can be drawn.

8. The reduction of heaving appears to be associated with a reduction of surface tension, and also possibly with the dispersing characteristics of the admixtures as well as the increase in viscosity.

B. FIELD INVESTIGATIONS

General:

The field investigations consisted of obtaining elevations of certain locations on the C.N.R. line west of Edmonton, at intervals throughout the winter, referred to previously-set benchmarks (Fig. 29). These areas were at Spruce Grove, Stony Plain and Fallis. All the locations had been previously treated with Lignosol. At Fallis, two untreated sections were also investigated.

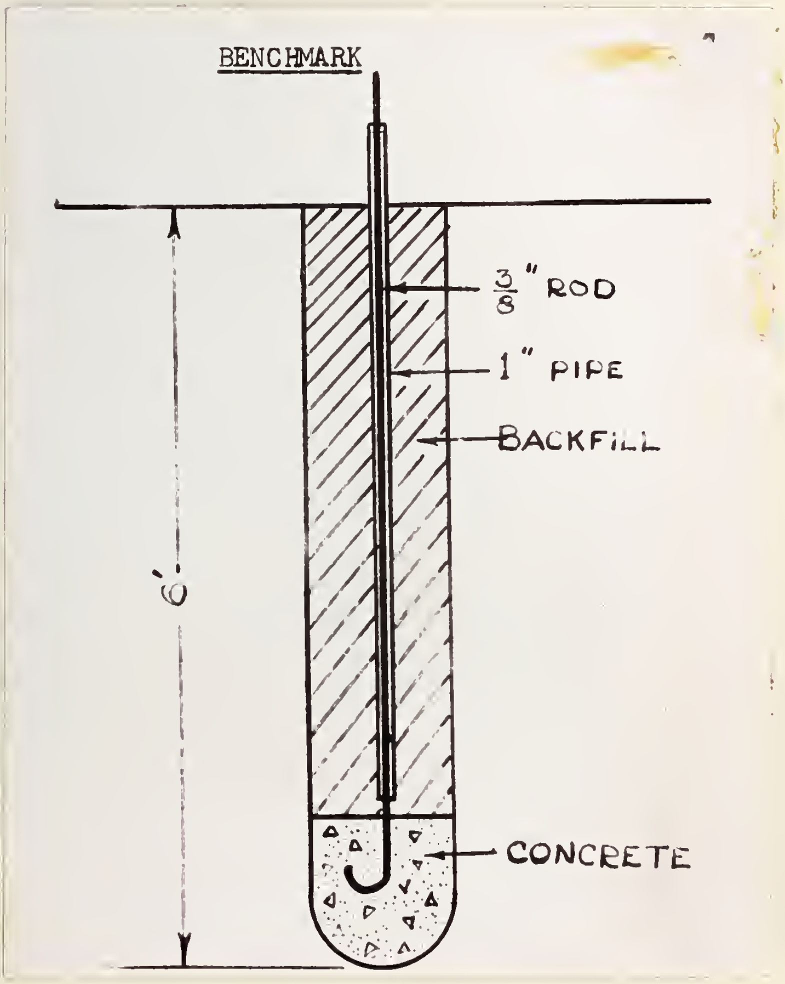


Fig. 29. Benchmark.

History of Treated Areas:

The railroad subgrade consisted generally of a mixture of fine sand and silt (Table XVII) running over low-lying, muskeg-covered land. The water table was from seven to ten feet below the surface, rising to within five feet of the surface in the spring, due to the thaw, and in the fall, due to the rains.

All three areas were treated in 1950-51 (Plans I to IV), but because there was a considerable difference in the effect of the injection at the three sites, Stony Plain was re-treated in December, 1951.

Injection

Although no treatment was carried out in this program, it is felt that a brief description of the method used should be noted.

The field treatment of the heaving areas consisted of forcing a Lignosol solution into the ground by a 1/2-inch Foreman rotary gear pump powered by a 5/8 H.P. Johnson engine. The solution passed through a 1-inch pipe, five feet long, perforated with 1/4-inch holes for one foot at the bottom. The operating pressure was generally between 10 and 15 p.s.i.

The spacing of the injection holes was such that complete saturation of the soil between them resulted. A state of saturation was evidenced by bubbling of Lignosol in adjacent holes. The holes were approximately ten feet apart. Forty-five gallons of solution were adequate for each hole, the solution strengths being between 33% and 35% by weight. Lignosol BD was used throughout.

Field Results

Plans I to IV show the location of injection points, the amount of Lignosol solution injected, and when it was injected. These Plans show the heaves of the ties at intervals throughout the past three winters. The elevations before any heaving had taken place were taken each year while the temperature was still above zero. These "zero" readings for the three years did not check with each other at Fallis, due to the replacement of some of the heaving subgrade material with gravel, and subsequent re-laying of the ties. The heaves therefore have been related to the zero readings taken each year. At Stony Plain and Spruce Grove, after the freezing period, the ties did not settle to the same elevations at which they had been, previous to the winter. Therefore, each plot of the heave for any particular site has been related to a different "zero" set of levels.

The "set" points were nails driven into the tops of every second tie for a distance covering the treated zones. They were set on the portions protruding past the rails, on the outsides of the tracks.

Readings were taken to one-hundredth of a foot with the rod held directly on the "set" nails. During the winter a flame-thrower was used to remove the ice covering on the ties.

The degree of freezing may be expressed by the cumulative number of degree days of freezing temperatures experienced by the soil. This value has been termed the Freezing Index, a high index indicating a cold winter, and a low one, indicating a mild winter such as that of 1952-53. A heaving region may act proportionately to the Freezing Index, but not necessarily. The Freezing Index is a measure of the likely depth of frost penetration.

TABLE XXVI. CHAINAGES OF LEVEL POINTS AT TEST SITES

FALLIS (Referred to Mile 50 Signpost)

Tie No.	Chainage	Tie No.	Chainage	Tie No.	Chainage
8W	13.5W	43	453.0	73	738.8
6W	10.2W	45	456.4	75	742.6
4W	6.0W	47	460.7	77	746.4
2W	2.8W	49	463.6	79	749.3
1	1.0E	51	467.2	81	752.6
3	5.0E	53	470.3	83	756.0
5	8.9	55	473.3	85	760.1
7	12.0	57	476.5	87	762.9
9	16.0	59	480.0	89	767.0
11	19.2	61	483.9	91	770.6
13	23.5	63	487.7	93	774.0
15	26.8	65	491.4	95	777.8
17	30.9	67	494.9	97	781.2
19	34.0	69	498.8	99	784.9
21	38.5	71	502.4	101	789.0
23	41.2			103	792.8
25	44.8			105	796.4
27	48.6			107	799.3
29	52.5			109	802.7
31	55.5			111	806.6
33	57.8			113	810.9
35	62.0			115	815.1
37	65.8			117	819.0
39	69.5				
41	73.3				

Untreated sections at Fallis - Ties 43 - 117 inclusive.

SPRUCE GROVE (Referred to First Tie East of Level Crossing)

Tie No.	Chainage
0	0
2	3.4
4	6.1
6	9.5
8	13.1
10	16.8
12	19.5
14	23.5
16	27.1
18	30.6
20	34.5
22	38.2
24	42.4
26	45.2
28	49.1
30	52.5
32	55.8

STONY PLAIN (Referred to Mark on North Rail)

Tie No.	Chainage	Tie No.	Chainage
4W	12.5	24	43.4
3W	9.1	26	46.0
2W	5.4	28	49.0
1W	1.7W	30	52.2
2E	2.5E	32	56.0
4E	6.5E	34	59.9
6	10.1	36	63.8
8	13.3	38	66.9
10	17.0	40	70.0
12	20.8	42	73.0
14	24.3	44	76.0
16	27.8	46	79.0
18	31.5	48	82.3
20	35.5	50	84.6
22	39.2	52	88.3

TABLE XXVI(a). LEVELS, 1952-1953, LIGNOSOL-TREATED
TEST SECTION - FALLIS

NORTH SIDE OF TRACKS

Tie No.	Nov. 10	Jan. 17	Heave	Feb. 10	Total Heave	March 16	Total Heave
8W	99.93	99.98	0.05	100.01	0.08	100.00	0.07
6W	.94	.99	0.05	100.01	0.07	.01	0.07
4W	.94	.97	0.03	.01	0.07	.01	0.07
2W	.98	100.02	0.04	.03	0.05	.05	0.07
1	99.95	99.99	0.04	100.02	0.07	.01	0.06
3	.94	100.00	0.06	.02	0.08	.01	0.07
5	.92	99.99	0.07	.00	0.08	99.98	0.06
7	.88	.95	0.07	99.98	0.10	.97	0.09
9	.92	100.02	0.10	100.04	0.12	100.05	0.13
11	.93	.04	0.11	.07	0.14	.07	0.14
13	.90	.03	0.13	.06	0.16	.07	0.17
15	.92	.05	0.13	.10	0.18	.09	0.17
17	100.01	.14	0.13	.19	0.18	.18	0.17
19	99.92	.04	0.12	.08	0.16	.08	0.16
21	.83	99.94	0.11	99.99	0.16	99.98	0.15
23	.88	.98	0.10	100.01	0.13	100.01	0.13
25	.89	.97	0.06	.00	0.11	99.99	0.10
27	.84	.90	0.06	99.93	0.09	.91	0.07
29	.83	.86	0.03	.89	0.06	.87	0.04
31	.80	.83	0.03	.85	0.05	.83	0.03
33	.82	.86	0.04	.87	0.05	.86	0.04
35	.84	.89	0.04	.90	0.06	.89	0.05
37	.83	.87	0.04	.90	0.07	.89	0.06
39	.83	.88	0.05	.90	0.07	.90	0.07
41	.78	.82	0.04	.84	0.06	.84	0.06

TABLE XXVI(b). LEVELS, 1952-1953, LIGNOSOL-TREATED TEST SECTION - FALLIS

SOUTH SIDE OF TRACKS

Tie. No.	Nov. 10	Jan. 17	Heave	Feb. 10	Total Heave	March 16	Total Heave
8W	99.98	99.99	0.01	100.03	0.05	100.00	0.02
6W	.99	100.02	0.03	.05	0.06	.03	0.04
4W	.93	99.95	0.02	99.97	0.04	99.95	0.02
2W	100.01	100.05	0.04	100.06	0.05	100.05	0.04
1	99.97	100.00	0.03	100.02	0.05	.00	0.03
3	.98	.02	0.04	.04	0.06	.02	0.04
5	.97	.00	0.03	.03	0.06	.00	0.03
7	.90	99.95	0.05	99.96	0.06	99.94	0.04
9	.93	99.99	0.06	100.02	0.09	100.00	0.07
11	.93	100.02	0.09	.04	0.09	.03	0.10
13	.99	.08	0.09	.11	0.12	.10	0.11
15	.92	.02	0.10	.04	0.12	.04	0.12
17	.94	.04	0.10	.07	0.13	.06	0.12
19	100.00	.03	0.03	.06	0.06	.06	0.06
21	99.87	99.93	0.06	99.96	0.11	99.96	0.13
23	.93	100.00	0.07	100.01	0.08	100.01	0.08
25	.88	99.90	0.02	99.93	0.05	99.92	0.04
27	.85	.87	0.02	.89	0.04	.87	0.02
29	.85	.86	0.01	.88	0.03	.87	0.02
31	.83	.84	0.01	.86	0.03	.83	0.00
33	.88	.90	0.02	.91	0.03	.89	0.02
35	.82	.83	0.01	.84	0.02	.83	0.01
37	.84	.86	0.02	.87	0.03	.86	0.02
39	.80	.81	0.01	.83	0.03	.82	0.02
41	.81	.82	0.02	.84	0.03	.83	0.02

TABLE XXVI(c). LEVELS, 1952-1953, UNTREATED TEST SECTIONS - FALLIS

NORTH SIDE OF TRACKS

Tie No.	Nov. 10	Jan. 17	Heave	Feb. 10	Total Heave	March 16	Total Heave
43	99.34	99.59	0.25	99.68	0.34	99.70	0.36
45	.37	.63	0.26	.71	0.34	.74	0.37
47	.37	.64	0.27	.67	0.30	.76	0.39
49	.35	.63	0.28	.66	0.31	.75	0.40
51	.32	.59	0.27	.63	0.31	.72	0.40
53	.28	.56	0.28	.65	0.37	.68	0.40
55	.27	.55	0.28	.64	0.37	.67	0.40
57	.34	.63	0.29	.71	0.37	.75	0.41
59	.27	.56	0.29	.64	0.37	.67	0.40
61	.27	.56	0.29	.64	0.37	.67	0.40
63	.29	.59	0.30	.66	0.37	.70	0.41
65	.29	.58	0.29	.65	0.36	.69	0.40
67	.27	.56	0.29	.63	0.36	.67	0.40
69	.31	.58	0.27	.65	0.34	.69	0.38
71	.31	.55	0.24	.63	0.32	.66	0.35
73	98.97	99.04	0.07	99.09	0.12	99.07	0.10
75	.95	.03	0.08	.08	0.13	.05	0.10
77	.95	.02	0.07	.07	0.12	.05	0.10
79	.91	98.98	0.07	.03	0.12	.00	0.09
81	.92	99.01	0.09	.07	0.15	.03	0.11
83	.92	.01	0.09	.06	0.14	.05	0.13
85	.90	.07	0.17	.14	0.24	.11	0.21
87	.92	.14	0.22	.22	0.30	.20	0.28
89	.89	.19	0.30	.27	0.38	.27	0.38
91	.92	.27	0.35	.37	0.45	.38	0.46
93	.86	.22	0.36	.34	0.48	.37	0.51
95	.87	.23	0.36	.37	0.50	.40	0.53
97	.87	.21	0.34	.36	0.49	.39	0.52
99	.88	.21	0.33	.36	0.48	.38	0.50
101	.94	.25	0.31	.41	0.47	.43	0.49
103	.88	.17	0.29	.34	0.46	.37	0.49
105	.83	.10	0.27	.26	0.43	.30	0.47
107	.82	.08	0.26	.23	0.41	.28	0.46
109	.83	.08	0.25	.23	0.40	.27	0.44
111	.80	.01	0.21	.16	0.36	.19	0.39
113	.82	.00	0.18	.13	0.31	.15	0.33
115	.81	98.96	0.15	.08	0.27	.10	0.29
117	.81	.94	0.13	.06	0.25	.06	0.25

Ties 1-41, 2W, 4W, 6W and 8W - Treated.

TABLE XXVI(d). LEVELS, 1952-1953, UNTREATED
TEST SECTIONS - FALLIS

SOUTH SIDE OF TRACKS

Tie No.	Nov. 10	Jan. 17	Heave	Feb. 10	Total Heave	March 16	Total Heave
43	99.31	99.49	0.18	99.57	0.26	99.57	0.26
45	.31	.50	0.19	.56	0.25	.57	0.26
47	.31	.51	0.20	.57	0.26	.59	0.28
49	.35	.55	0.20	.60	0.25	.64	0.29
5.	.29	.49	0.20	.54	0.25	.57	0.28
53	.30	.50	0.20	.55	0.25	.57	0.27
55	.25	.45	0.20	.50	0.25	.56	0.31
57	.34	.55	0.21	.60	0.26	.66	0.32
59	.25	.46	0.21	.52	0.27	.57	0.32
61	.34	.57	0.23	.63	0.29	.65	0.31
63	.23	.48	0.25	.54	0.31	.56	0.33
65	.27	.52	0.25	.58	0.31	.61	0.34
67	.23	.49	0.26	.55	0.32	.58	0.35
69	.25	.48	0.23	.54	0.29	.56	0.31
71	.24	.46	0.22	.51	0.27	.54	0.30
73	98.87	99.00	0.13	99.01	0.14	99.02	0.15
75	.92	98.98	0.06	.00	0.08	.00	0.08
77	.90	.95	0.05	98.96	0.06	98.96	0.06
79	.90	.93	0.03	.95	0.05	.95	0.05
81	.89	.92	0.03	.93	0.04	.94	0.05
83	.88	.96	0.07	.97	0.09	.97	0.09
85	.88	.92	0.04	.95	0.07	.95	0.07
87	.92	.97	0.05	99.00	0.08	99.00	0.08
89	.91	.98	0.07	.00	0.09	98.99	0.08
91	.87	.96	0.09	.00	0.13	.99	0.12
93	.84	.97	0.13	----	----	99.02	0.18
95	.86	.99	0.13	.05	0.19	.05	0.19
97	.86	99.00	0.14	----	----	0.07	0.21
99	.84	.00	0.16	.08	0.24	.09	0.25
101	.87	.05	0.18	.12	0.25	.15	0.28
103	.83	.01	0.18	.09	0.26	.11	0.28
105	.84	.01	0.17	.08	0.24	.09	0.25
107	.82	98.97	0.15	.06	0.24	.07	0.25
109	.83	.98	0.15	.09	0.26	.09	0.26
111	.82	.95	0.13	.04	0.22	99.03	0.21
113	.84	.92	0.03	.02	0.18	98.99	0.15
115	.78	.88	0.10	98.97	0.19	.95	0.17
117	.78	.88	0.10	.96	0.18	.95	0.17

Ties 1-41, 4W, 6W and 8W - Treated.

TABLE XXVI(e). LEVELS, 1952-1953, LIGNOSOL-TREATED TEST SECTIONS - SPRUCE GROVE

NORTH SIDE OF TRACKS

Tie No.	Nov. 10	Jan. 17	Heave	Feb. 3	Total Heave	March 16	Total Heave
0	96.48	96.56	0.08	96.56	0.08	96.58	0.10
2	.51	.61	0.10	.61	0.10	.63	0.12
4	.50	.60	0.10	.61	0.11	.63	0.13
6	.42	.53	0.11	.53	0.11	.55	0.13
8	.40	.49	0.09	.51	0.11	.54	0.14
10	.38	.47	0.09	.51	0.13	.55	0.17
12	.46	.56	0.10	.60	0.14	.65	0.19
14	.42	.56	0.14	.60	0.18	.65	0.23
16	.40	.55	0.15	.60	0.20	.64	0.24
18	.36	.52	0.16	.55	0.19	.61	0.25
20	.38	.51	0.13	.56	0.18	.59	0.21
22	.33	.46	0.13	.49	0.16	.52	0.19
24	.37	.50	0.13	.53	0.16	.55	0.18
26	.37	.50	0.13	.52	0.15	.54	0.17
28	.35	.45	0.10	.47	0.12	.50	0.15
30	.34	.42	0.08	.45	0.11	.48	0.14
32	.28	.35	0.07	.40	0.12	.46	0.18

SOUTH SIDE OF TRACKS

Tie No.	Nov. 10	Jan. 17	Heave	Feb. 3	Total Heave	March 16	Total Heave
0	96.46	96.51	0.05	96.54	0.08	96.53	0.07
2	.46	.53	0.07	.55	0.09	.54	0.08
4	.46	.54	0.08	.55	0.09	.55	0.09
6	.42	.49	0.07	.51	0.09	.51	0.09
8	.42	.50	0.08	.53	0.11	.54	0.12
10	.40	.48	0.08	.52	0.12	.55	0.15
12	.45	.56	0.11	.61	0.16	.65	0.20
14	.38	.51	0.13	.56	0.18	.58	0.20
16	.36	.50	0.14	.55	0.19	.60	0.24
18	.34	.48	0.14	.52	0.18	.56	0.22
20	.39	.52	0.13	.55	0.16	.58	0.19
22	.32	.43	0.11	.45	0.13	.49	0.17
24	.37	.47	0.10	.50	0.13	.52	0.15
26	.36	.46	0.10	.48	0.12	.52	0.16
28	.35	.44	0.09	.48	0.13	.52	0.17
30	.34	.44	0.10	.47	0.13	.51	0.17
32	.27	.37	0.10	.40	0.13	.43	0.16

TABLE XXVI(f). LEVELS, 1952-1953, LIGNOSOL-TREATED TEST SECTIONS - STONY PLAIN

NORTH SIDE OF TRACKS

Tie No.	Nov. 10	Jan. 17	Heave	Feb. 3	Total Heave	March 16	Total Heave
4W	96.93	97.02	0.09	96.97	0.04	97.02	0.09
3W	.87	96.94	0.07	.91	0.04	96.96	0.09
2W	.89	.91	0.02	.94	0.05	97.00	0.11
1W	.81	.89	0.07	.88	0.04	96.93	0.12
2	.81	.94	0.13	.90	0.09	.95	0.14
4	.83	.93	0.10	.93	0.10	.97	0.14
6	.88	.94	0.06	.98	0.10	.95	0.07
8	.78	.88	0.10	.88	0.10	.94	0.16
10	.73	.86	0.13	.89	0.16	.94	0.21
12	.75	.83	0.08	.86	0.11	.90	0.15
14	.78	.87	0.09	.88	0.10	.94	0,16
16	.79	.86	0.07	.91	0.12	.97	0.18
18	.73	.83	0.10	.87	0.14	.92	0.19
20	.73	.85	0.12	.90	0.17	.96	0.23
22	.84	.91	0.07	97.03	0.19	97.09	0.25
24	.76	.89	0.13	96.95	0.19	97.00	0.24
26	.73	.90	0.17	.92	0.19	96.97	0.24
28	.81	.91	0.10	97.01	0.20	97.06	0.25
30	.76	.91	0.15	96.97	0.21	97.02	0.26
32	.72	.84	0.12	.94	0.22	97.00	0.26
34	.74	.87	0.13	.95	0.21	97.00	0.26
36	.68	.77	0.09	.88	0.20	96.92	0.24
38	.71	.76	0.05	.89	0.18	.94	0.23
40	.67	.73	0.06	.82	0.15	.87	0.20
42	.65	.71	0.06	.78	0.13	.83	0.18
44	.61	.67	0.06	.73	0.12	.77	0.16
46	.59	.65	0.06	.71	0.12	.74	0.15
48	.59	.64	0.05	.69	0.10	.72	0.13
50	.56	.64	0.08	.67	0.11	.68	0.12
52	.56	.65	0.09	.67	0.11	.69	0.13

TABLE XXVI(g). LEVELS, 1952-1953, LIGNOSOL-TREATED TEST SECTIONS - STONY PLAIN

SOUTH SIDE OF TRACKS

Tie No.	Nov. 10	Jan. 17	Heave	Feb. 3	Total Heave	March 16	Total Heave
4W	96.98	96.98	0	97.03	0.05	97.08	0.10
3W	.91	.91	0	96.95	0.04	97.00	0.09
2W	.86	.94	0.08	.92	0.06	96.97	0.11
1W	.84	.87	0.03	.91	0.07	96.97	0.13
2	.89	.90	0.01	.98	0.09	97.03	0.14
4	.87	.91	0.04	.97	0.10	.02	0.15
6	.87	.95	0.08	.97	0.10	.04	0.17
8	.80	.87	0.07	.90	0.10	96.96	0.16
10	.83	.87	0.04	.93	0.10	97.00	0.17
12	.76	.83	0.07	.87	0.11	96.91	0.15
14	.78	.86	0.08	.90	0.12	.95	0.17
16	.78	.87	0.09	.89	0.11	.95	0.17
18	.74	.82	0.08	.87	0.13	.92	0.18
20	.75	.85	0.10	.90	0.15	.96	0.21
22	.80	.95	0.15	.97	0.17	.02	0.23
24	.79	.87	0.08	.96	0.17	.02	0.23
26	.79	.85	0.06	.97	0.18	.04	0.25
28	.79	.93	0.04	.99	0.20	.06	0.27
30	.79	.89	0.10	97.00	0.21	.06	0.27
32	.72	.85	0.13	96.94	0.22	.00	0.28
34	.69	.87	0.18	.96	0.27	.03	0.34
38	.66	.82	0.18	.84	0.18	.89	0.23
40	.64	.76	0.12	.80	0.16	.84	0.20
42	.63	.72	0.09	.77	0.14	.81	0.18
44	.60	.68	0.08	.72	0.12	.75	0.15
46	.59	.65	0.06	.70	0.11	.73	0.14
48	.59	.64	0.05	.69	0.10	.72	0.13
50	.58	.62	0.04	.68	0.10	.70	0.12
52	.59	.63	0.04	.69	0.10	.70	0.11

TABLE XXVI(h). LEVELS, 1950-1951, LIGNOSOL-TREATED TEST SECTIONS - STONY PLAIN

NORTH SIDE OF TRACKS

Tie No.	Nov. 15	Jan. 6	Heave	Feb. 1	Total Heave	April 5	Total Heave
1W	96.82	96.89	0.07	96.94	0.12	97.04	0.22
2E	.81	.80	0.09	.95	0.14	.06	0.25
4	.82	.93	0.11	.98	0.16	.08	0.26
6	.85	.95	0.10	97.01	0.16	.12	0.27
8	.77	.88	0.11	96.93	0.16	.06	0.29
10	.77	.87	0.10	.93	0.16	.08	0.31
12	.75	.85	0.10	.91	0.16	.07	0.32
14	.75	.86	0.11	.93	0.18	.11	0.36
16	.75	.86	0.11	.94	0.19	.13	0.38
18	.67	.79	0.12	.88	0.21	.07	0.40
20	.69	.82	0.13	.92	0.23	.11	0.41
22	.80	.94	0.14	97.05	0.25	.24	0.44
24	.75	.89	0.14	97.00	0.25	.16	0.41
26	.73	.87	0.14	96.99	0.26	.13	0.40
28	.83	.96	0.13	97.08	0.25	,22	0.39
30	.78	.92	0.14	97.03	0.25	.17	0.39
32	.75	.88	0.13	96.99	0.24	.13	0.38
34	.75	.87	0.12	96.99	0.24	.13	0.38
36	.69	.81	0.12	.92	0.23	.06	0.37
38	.70	.81	0.11	.91	0.21	.06	0.36
40	.66	.77	0.11	.85	0.19	96.99	0.33
42	.68	.76	0.09	.84	0.16	96.96	0.28
44	.68	.76	0.09	.82	0.14	.93	0.25
46	.67	.73	0.06	.79	0.12	.88	0.21
48	.64	.69	0.05	.74	0.10	.82	0.18
50	.71	.76	0.05	.79	0.08	.88	0.17
52	.68	.73	0.05	.76	0.08	.83	0.15

TABLE XXVI(i). LEVELS, 1950-1951, LIGNOSOL-TREATED TEST SECTIONS - STONY PLAIN

SOUTH SIDE OF TRACKS

Tie No.	Nov. 15	Jan. 6	Heave	Feb. 1	Total Heave	April 5	Total Heave
1W	96.85	96.92	0.07	96.96	0.11	97.07	0.22
2E	.89	.98	0.09	97.02	0.13	.14	0.25
4	.86	.96	0.10	97.01	0.15	.13	0.27
6	.88	.97	0.09	97.03	0.15	.15	0.27
8	.81	.91	0.10	96.96	0.15	.11	0.30
10	.84	.93	0.09	.99	0.15	.15	0.31
12	.77	.87	0.10	.93	0.16	.11	0.34
14	.78	.89	0.11	.95	0.17	.14	0.36
16	.77	.87	0.10	.94	0.17	.15	0.38
18	.73	.83	0.10	.91	0.18	.12	0.39
20	.75	.86	0.11	.95	0.20	.16	0.41
22	.78	.90	0.12	97.01	0.23	.22	0.44
24	.78	.90	0.12	.02	0.24	.22	0.44
26	.79	.91	0.12	.04	0.25	.23	0.44
28	.80	.93	0.13	.06	0.26	.24	0.44
30	.79	.93	0.14	.06	0.27	.24	0.45
32	.72	.86	0.14	96.99	0.27	.17	0.45
34	.77	.90	0.13	97.03	0.26	.21	0.44
36	.69	.81	0.12	96.92	0.23	.11	0.42
38	.69	.81	0.12	.90	0.21	.09	0.40
40	.67	.77	0.10	.85	0.18	.03	0.36
42	.69	.78	0.09	.84	0.15	97.00	0.31
44	.71	.78	0.07	.83	0.12	96.96	0.25
46	.70	.76	0.06	.80	0.10	.93	0.23
48	.67	.72	0.05	.76	0.09	.87	0.20
50	.72	.77	0.05	.79	0.07	.90	0.18
52	.71	.72	0.01	.78	0.07	.87	0.16

TABLE XXVI(j). LEVELS, 1951-1952, LIGNOSOL-TREATED TEST SECTIONS - STONY PLAIN

NORTH SIDE OF TRACKS

Tie No.	Aug. 6	Jan. 26	Heave	Feb. 15	Total Heave	April 5	Total Heave
1W	96.85	96.94	0.09	97.01	0.16	97.04	0.19
2E	.83	.96	0.13	.06	0.23	.06	0.23
4	.85	.99	0.14	.08	0.23	.11	0.26
6	.91	97.06	0.15	.13	0.22	.16	0.25
8	.81	96.99	0.18	.07	0.26	.08	0.27
10	.81	.98	0.17	.07	0.26	.09	0.28
12	.78	.95	0.17	.06	0.28	.10	0.32
14	.81	.97	0.16	.09	0.28	.13	0.32
16	.81	97.01	0.20	.12	0.31	.17	0.36
18	.75	96.96	0.21	.07	0.32	.14	0.39
20	.77	97.01	0.24	.10	0.33	.18	0.41
22	.76	.13	0.37	.22	0.46	.28	0.52
24	.80	.05	0.25	.14	0.34	.20	0.40
26	.74	.02	0.26	.12	0.38	.16	0.42
28	.83	.13	0.30	.20	0.37	.23	0.40
30	.78	.07	0.29	.14	0.36	.18	0.40
32	.75	.02	0.27	.11	0.36	.16	0.41
34	.77	97.04	0.27	.11	0.34	.17	0.40
36	.69	96.97	0.28	.05	0.36	.13	0.44
38	.72	.95	0.23	.04	0.34	.13	0.41
40	.69	.90	0.21	96.98	0.29	.04	0.35
42	.68	.87	0.19	.95	0.27	.01	0.33
44	.63	.87	0.24	.92	0.29	96.98	0.35
46	.61	.82	0.21	.88	0.27	.96	0.35
48	.61	.77	0.16	.82	0.21	.90	0.29
50	.58	.81	0.23	.86	0.28	.93	0.35
52	.58	.80	0.22	.83	0.25	.86	0.28

TABLE XXVI(k). LEVELS, 1951-1952, LIGNOSOL-TREATED TEST SECTIONS - STONY PLAIN

SOUTH SIDE OF TRACKS

Tie No.	Aug. 6	Jan. 26	Heave	Feb. 15	Total Heave	April 5	Total Heave
1W	96.84	96.99	0.15	97.10	0.17	97.08	0.24
2E	.91	97.04	0.13	.14	0.23	.15	0.24
4	.90	97.05	0.15	.14	0.24	.15	0.25
6	.89	.06	0.17	.14	0.25	.16	0.27
8	.82	.03	0.21	.08	0.26	.13	0.31
10	.85	.01	0.16	.12	0.27	.15	0.30
12	.78	96.95	0.17	.07	0.29	.12	0.34
14	.81	97.00	0.19	.11	0.30	.17	0.36
16	.80	97.00	0.20	.12	0.32	.20	0.40
18	.76	96.97	0.21	.09	0.33	.16	0.40
20	.78	97.00	0.22	.11	0.33	.19	0.41
22	.82	97.07	0.25	.18	0.36	.24	0.42
24	.81	.06	0.25	.18	0.37	.23	0.42
26	.81	.08	0.27	.18	0.37	.22	0.41
28	.81	.09	0.28	.17	0.36	.22	0.41
30	.80	.09	0.29	.18	0.38	.21	0.41
32	.73	.02	0.29	.11	0.38	.15	0.42
34	.77	.05	0.28	.13	0.36	.17	0.40
36	.78	96.96	0.18	.05	0.27	.07	0.29
38	.78	.93	0.15	.02	0.24	.07	0.29
40	.76	.86	0.10	96.95	0.19	.03	0.27
42	.74	.84	0.10	.92	0.18	96.97	0.23
44	.61	.83	0.22	.91	0.30	.97	0.36
46	.62	.81	0.19	.88	0.26	.94	0.32
48	.61	.77	0.16	.83	0.22	.91	0.30
50	.59	.81	0.22	.88	0.29	.94	0.35
52	.61	.81	0.20	.90	0.29	.90	0.29

TABLE XXVI(1). LEVELS, 1950-51 and 1951-52, LIGNOSOL-TREATED TEST SECTIONS - FALLIS

NORTH SIDE OF TRACKS

Tie No.	Nov. 15 1950	March 29 1951	Heave	Aug. 6 1951	Feb. 15 1952	Heave
8W	99.98	100.03	0.05	99.95	100.03	0.08
6W	100.00	100.05	0.05	.97	100.05	0.08
4W	99.98	100.04	0.06	.98	99.98	0.00
2W	100.05	100.09	0.03	100.03	100.06	0.03
1	100.03	100.07	0.04	100.00	.04	0.04
3	100.00	100.06	0.06	99.98	.05	0.07
5	99.97	100.03	0.06	.96	.03	0.07
7	.94	.01	0.07	.91	.03	0.07
9	.96	.07	0.11	.96	100.03	0.07
11	.97	.09	0.12	.95	.04	0.09
13	.94	.08	0.14	.93	.09	0.16
15	.96	.12	0.16	.95	.04	0.09
17	100.06	.21	0.15	100.03	.06	0.03
19	100.00	.12	0.12	99.95	.06	0.11
21	99.89	.02	0.13	.97	99.97	0.00
23	.92	.04	0.12	.91	100.01	0.10
25	.94	.03	0.09	.92	100.05	0.13
27	.89	99.97	0.08	.86	99.92	0.06
29	.87	.92	0.05	.87	.91	0.04
31	.82	.88	0.06	.85	.89	0.04
33	.87	.93	0.06	.87	.95	0.08
35	.85	.92	0.07	.88	.89	0.01
37	.84	.90	0.06	.88	.91	0.03
39	.83	.90	0.07	.88	.89	0.01
41	.79	.86	0.07	.84	.90	0.06

TABLE XXVI(m). LEVELS, 1950-51 and 1951-52, LIGNOSOL-TREATED TEST SECTIONS - FALLIS

SOUTH SIDE OF TRACKS

Tie No.	Nov. 15 1950	March 29 1951	Heave	Aug. 6 1951	Feb. 15 1952	Heave
8W	100.01	100.05	0.04	99.98	100.01	0.03
6W	100.02	.07	0.05	100.01	.02	0.01
4W	99.95	.00	0.05	99.95	.02	0.07
2W	100.03	.08	0.05	100.03	.06	0.03
1	100.03	.07	0.04	100.01	.04	0.03
3	100.03	.07	0.04	.02	.03	0.01
5	100.00	.04	0.04	.00	.00	0.00
7	99.97	99.99	0.02	99.96	99.99	0.03
9	100.00	100.04	0.04	.98	100.05	0.07
11	100.00	.04	0.04	.97	.06	0.09
13	100.02	.09	0.07	100.01	.05	0.04
15	99.96	.04	0.08	99.96	.08	0.12
17	.98	.05	0.07	.97	.07	0.10
19	.98	.05	0.07	.98	.08	0.10
21	.89	99.95	0.06	.90	99.99	0.09
23	.95	100.00	0.05	.87	100.03	0.16
25	.89	99.94	0.05	.91	100.03	0.12
27	.88	.92	0.04	.88	99.97	0.11
29	.87	.91	0.04	.89	.93	0.04
31	.84	.88	0.04	.86	.92	0.06
33	.90	.93	0.03	.91	.93	0.02
35	.83	.87	0.04	.86	.95	0.09
37	.85	.88	0.03	.88	.94	0.06
39	.82	.86	0.04	.84	.95	0.11
41	.83	.87	0.04	.86	.89	0.03

TABLE XXVI(n). LEVELS, 1950-51 and 1951-52, LIGNOSOL-TREATED TEST SECTIONS - SPRUCE GROVE

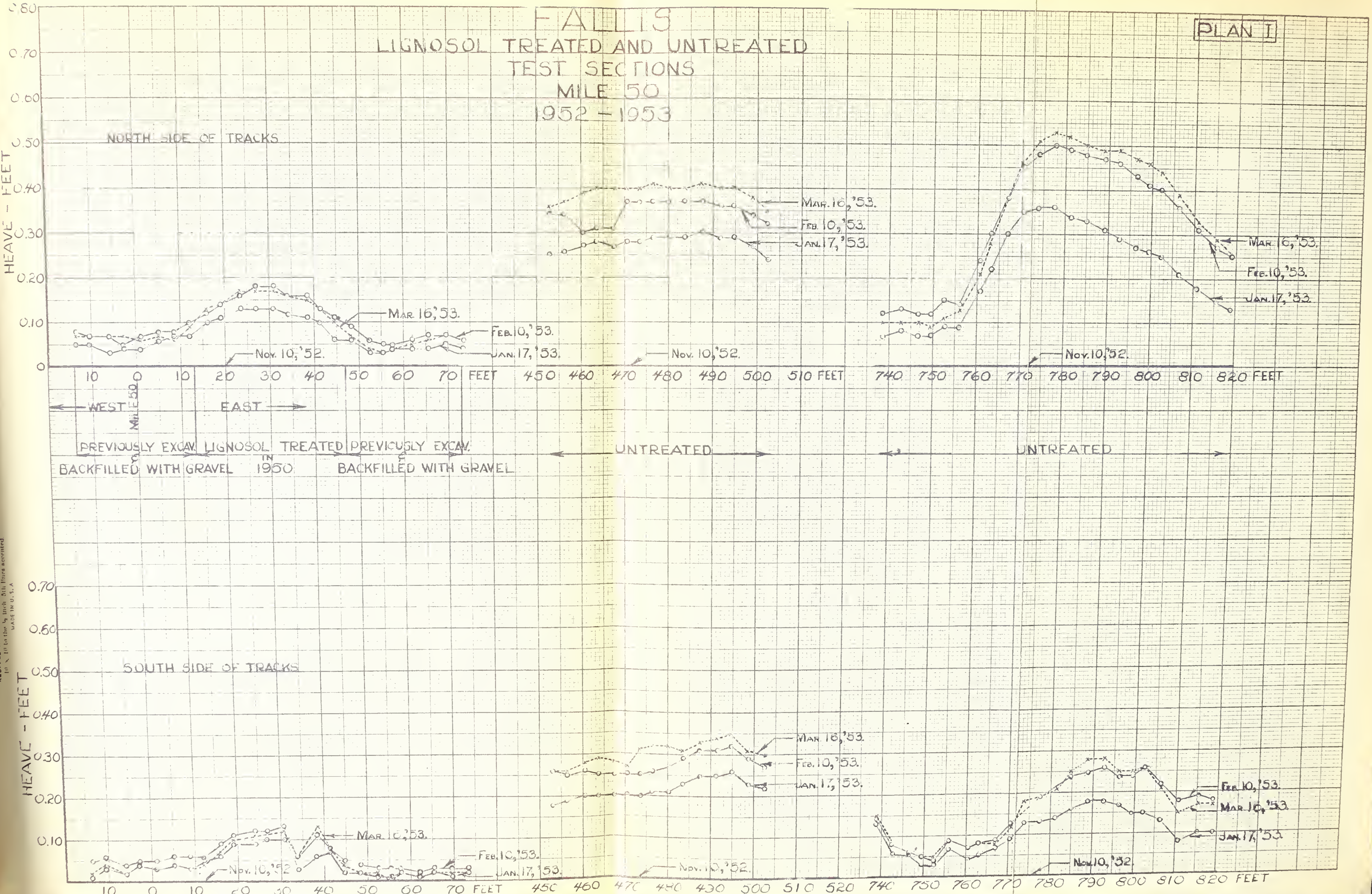
NORTH SIDE OF TRACKS

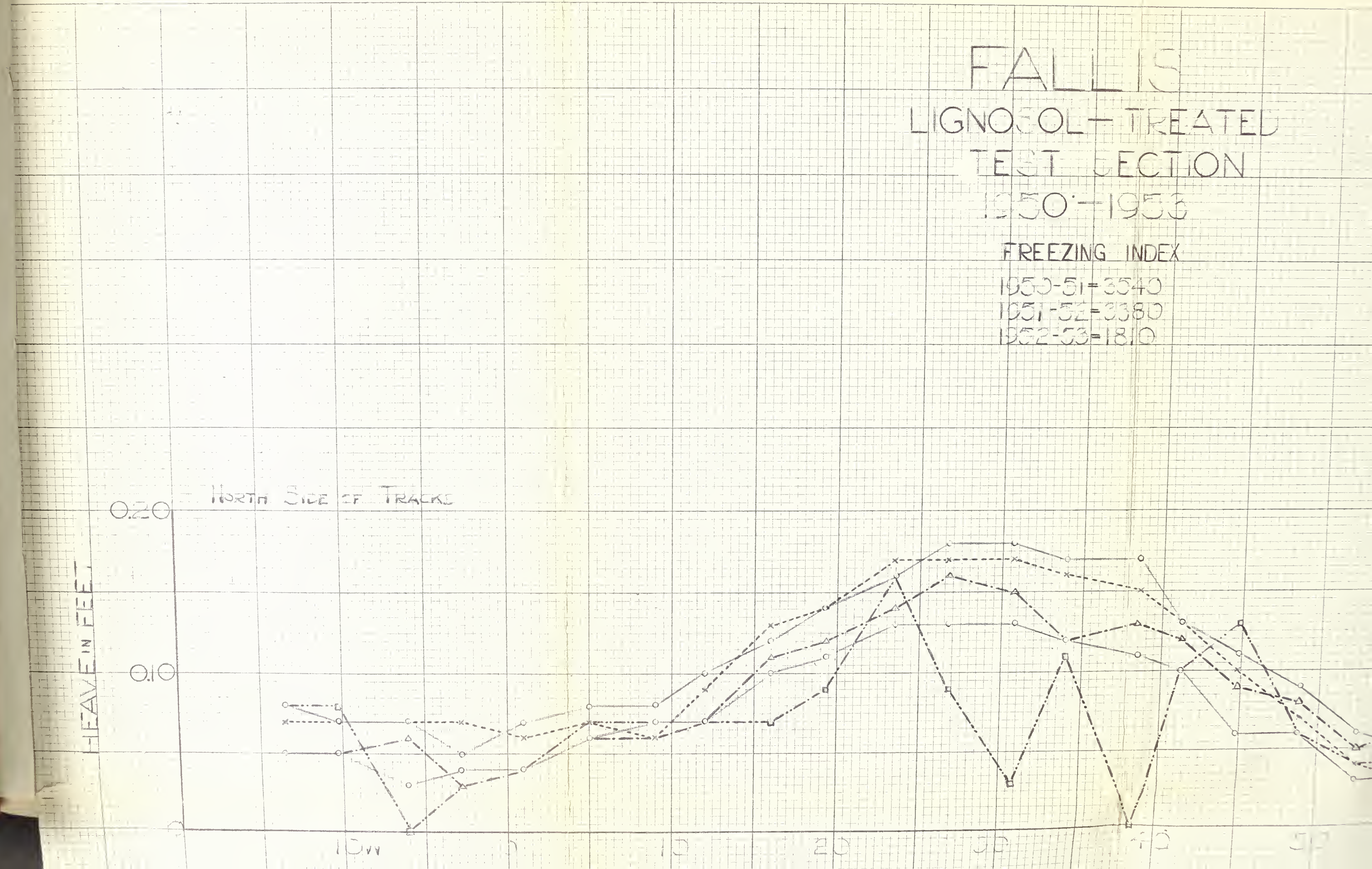
Tie No.	Nov. 15 1950	Dec. 7 1950	Heave	April 5 1951	Total Heave	Aug. 6 1951	Jan. 26 1952	Heave	April 5 1952	Total Heave
0	96.50	96.55	0.05	96.59	0.09	96.50	96.50	0.06	96.60	0.10
2	.51	.56	0.05	.60	0.09	.53	.59	0.06	.62	0.09
4	.49	.55	0.06	.59	0.10	.52	.57	0.05	.61	0.09
6	.44	.50	0.06	.53	0.09	.43	.49	0.06	.53	0.10
8	.46	.50	0.04	--	--	.41	.48	0.07	.53	0.12
10	.41	.43	0.02	.52	0.11	.38	.51	0.13	.55	0.17
12	.45	.47	0.02	.57	0.12	.44	.55	0.11	.63	0.19
14	.38	.42	0.04	.54	0.16	.38	.55	0.17	.62	0.24
16	.35	.40	0.05	.53	0.18	.35	.54	0.19	.61	0.26
18	.40	.46	0.06	.59	0.19	.32	.60	0.28	.68	0.36
20	.40	.40	0.00	.50	0.10	.32	.51	0.19	.58	0.26
22	.34	.40	0.06	.50	0.16	.27	.50	0.23	.57	0.30
24	.36	.42	0.06	.50	0.14	.31	.49	0.18	.57	0.26
26	.36	.42	0.06	.49	0.13	.31	.50	0.19	.57	0.26
28	.38	.44	0.06	.53	0.15	.30	.48	0.18	.57	0.27
30	.38	.42	0.04	.53	0.15	.29	.48	0.19	.56	0.27
32	.32	.37	0.05	.49	0.17	.26	.45	0.19	.53	0.27

TABLE XXVI(o). LEVELS, 1950-51 and 1951-52, LIGNOSOL-TREATED TEST SECTIONS - SPRUCE GROVE

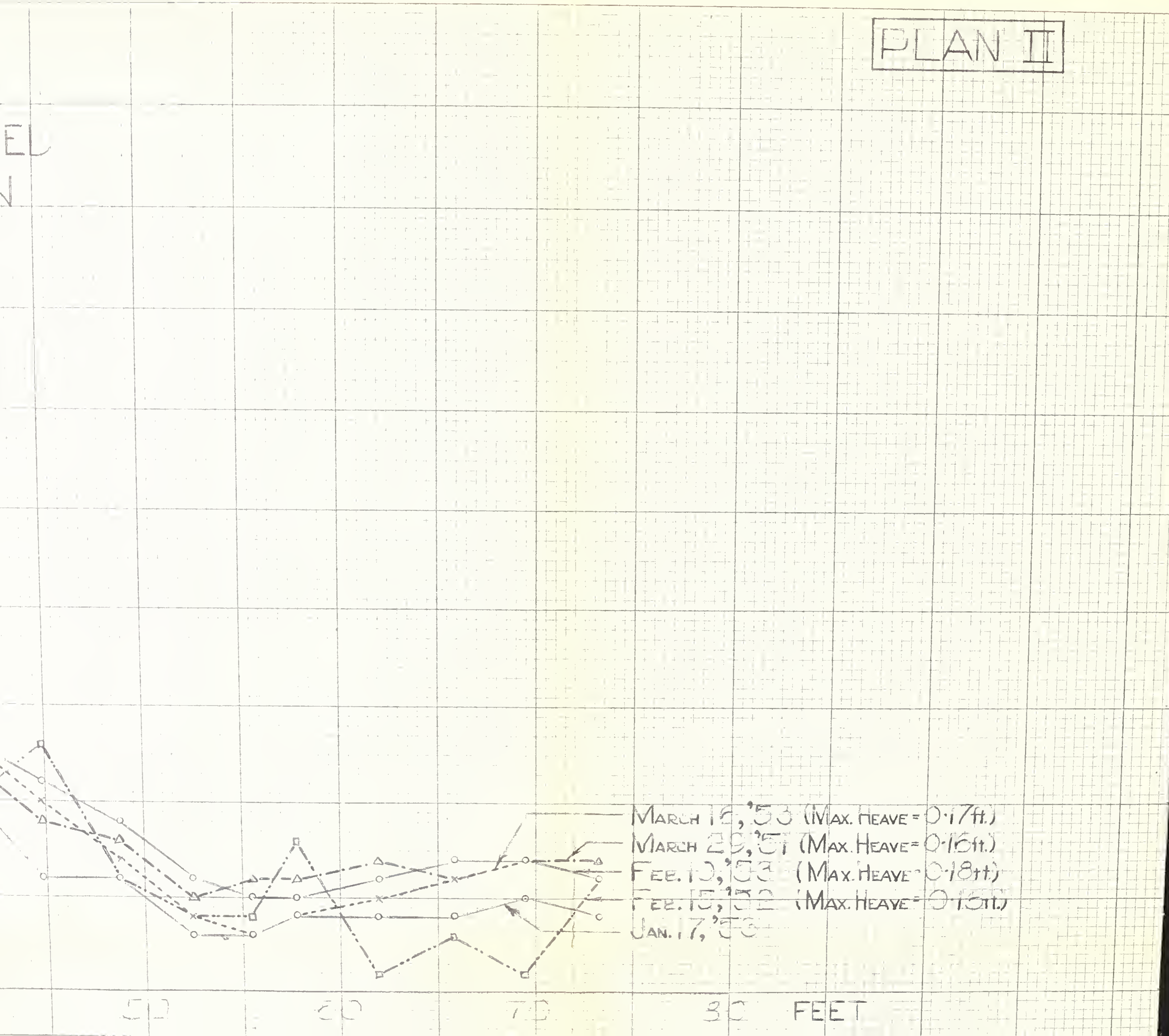
SOUTH SIDE OF TRACKS

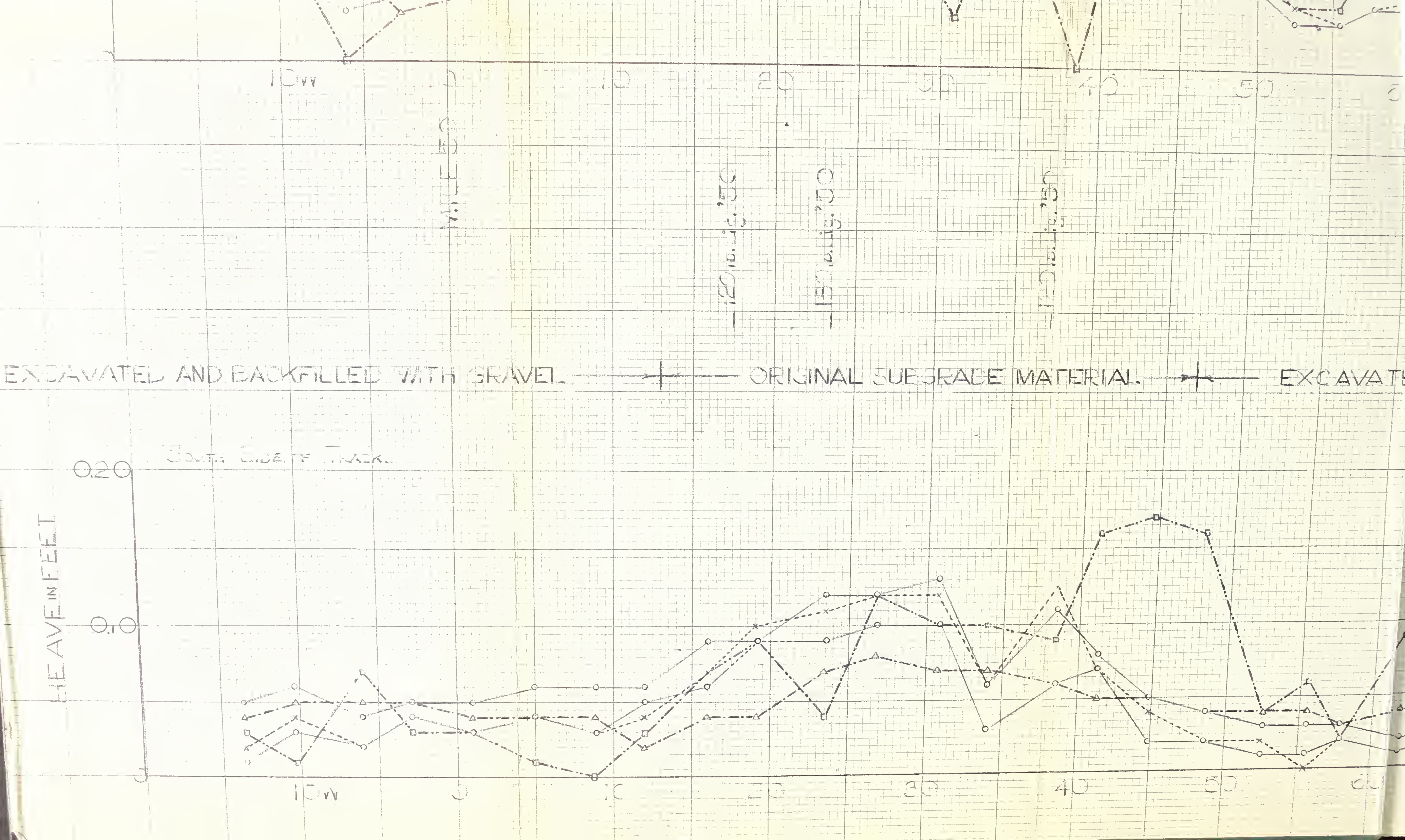
Tie No.	Nov. 15 1950	Dec. 7 1950	Heave	April 5 1951	Total Heave	Aug. 6 1951	Jan. 26 1952	Heave	April 5 1952	Total Heave
0	96.49	96.52	0.03	96.54	0.05	96.47	96.55	0.08	96.57	0.10
2	.45	.49	0.04	.51	0.06	.48	.54	0.06	.58	0.10
4	.43	.47	0.04	.50	0.07	.48	.54	0.06	.58	0.10
6	.44	.48	0.04	.50	0.06	.42	.51	0.09	.54	0.12
8	.39	.41	0.02	.46	0.07	.44	.51	0.07	.56	0.12
10	.34	.36	0.02	.43	0.09	.41	.53	0.12	.59	0.17
12	.36	.38	0.02	.48	0.12	.45	.55	0.10	.61	0.26
14	.33	.36	0.03	.47	0.14	.39	.53	0.14	.59	0.20
16	.34	.38	0.04	.48	0.14	.39	.55	0.16	.59	0.20
18	.37	.41	0.04	.52	0.15	.37	.60	0.23	.67	0.30
20	.29	.33	0.04	.43	0.14	.40	.53	0.13	.59	0.19
22	.36	.41	0.05	.49	0.13	.34	.50	0.16	.58	0.24
24	.35	.39	0.04	.47	0.12	.39	.49	0.10	.58	0.19
26	.34	.38	0.04	.48	0.14	.37	.49	0.12	.57	0.20
28	.39	.43	0.04	.55	0.16	.36	.49	0.13	.58	0.22
30	.40	.43	0.03	.56	0.16	.35	.50	0.15	.58	0.23
32	.32	.36	0.04	.49	0.17	.28	.44	0.16	.50	0.22


FALLIS
LIGNOSOL TREATED AND UNTREATED
TEST SECTIONS
MILE 50
1952 - 1953
PLAN I
NORTH SIDE OF TRACKS
HEAVE - FEET
0.80
0.70
0.60
0.50
0.40
0.30
0.20
0.10
0
MAR. 16, '53.
FEB. 10, '53.
JAN. 17, '53.
NOV. 10, '52.
10 0 10 20 30 40 50 60 70 FEET 450 460 470 480 490 500 510 FEET 740 750 760 770 780 790 800 810 820 FEET
WEST
EAST
MILE 50
PREVIOUSLY EXCAV. LIGNOSOL TREATED PREVIOUSLY EXCAV.
BACKFILLED WITH GRAVEL IN 1950 BACKFILLED WITH GRAVEL
UNTREATED
UNTREATED
SOUTH SIDE OF TRACKS
HEAVE - FEET
0.70
0.60
0.50
0.40
0.30
0.20
0.10
10 0 10 20 30 40 50 60 70 FEET 450 460 470 480 490 500 510 520 740 750 760 770 780 790 800 810 820 FEET

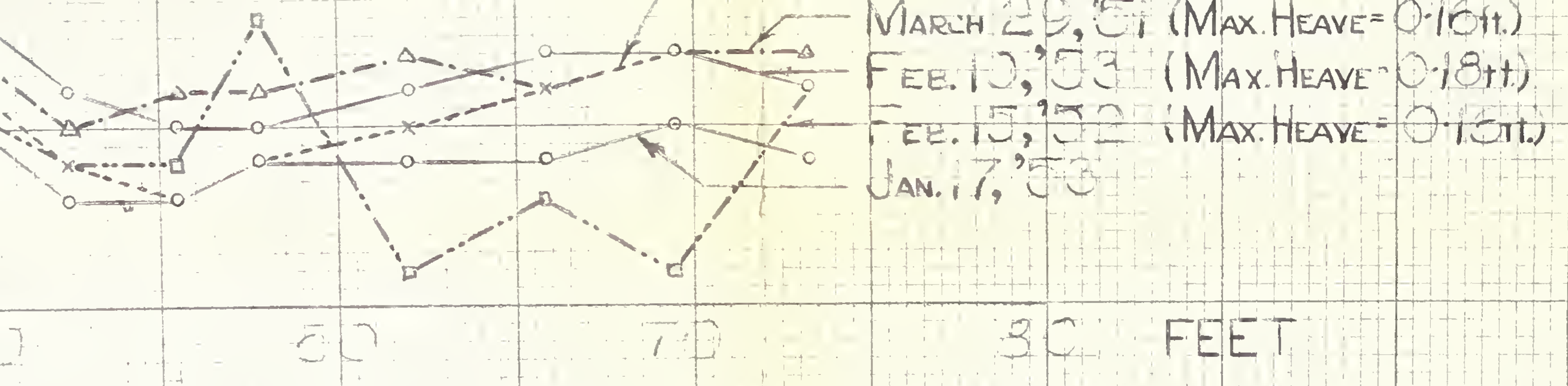


FALLIS
LIGNOSOL-TREATED
TEST SECTION
1950-1953
FREEZING INDEX
1950-51=3540
1951-52=3380
1952-53=1810
NORTH SIDE OF TRACKS
HEAVE IN FEET
0.20
0.10
0
10W
0
10
20
30
40
50

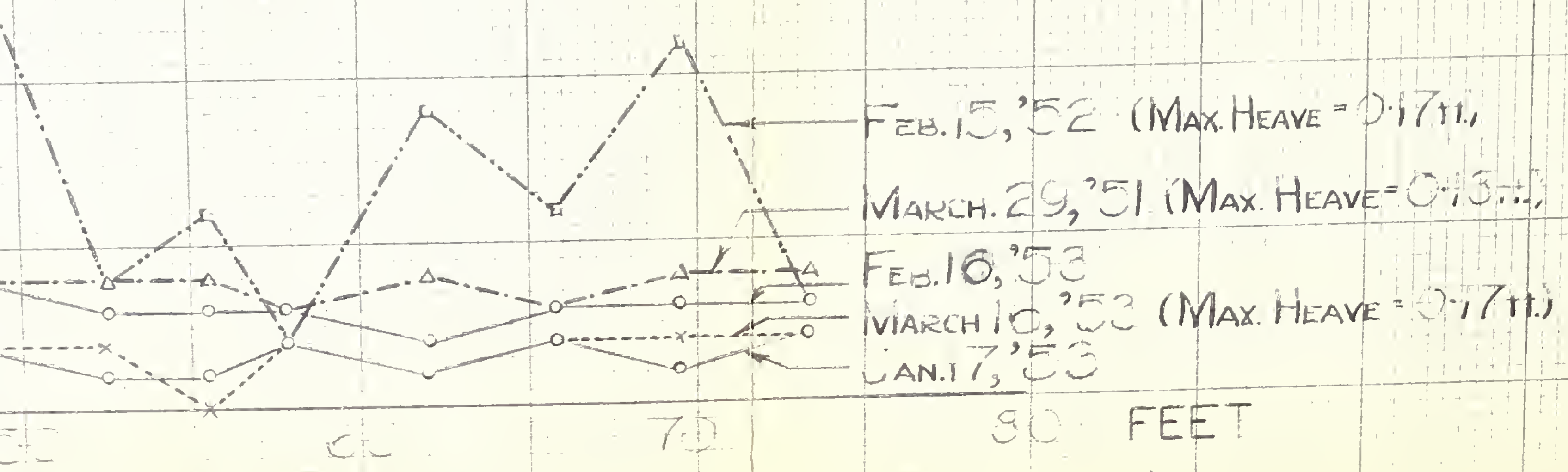

PLAN II
EL
N
MARCH 16, '53 (MAX. HEAVE = 0·17 ft.)
MARCH 29, '51 (MAX. HEAVE = 0·16 ft.)
FEB. 10, '53 (MAX. HEAVE = 0·18 ft.)
FEB. 15, '52 (MAX. HEAVE = 0·15 ft.)
JAN. 17, '56
50
60
70
80
FEET

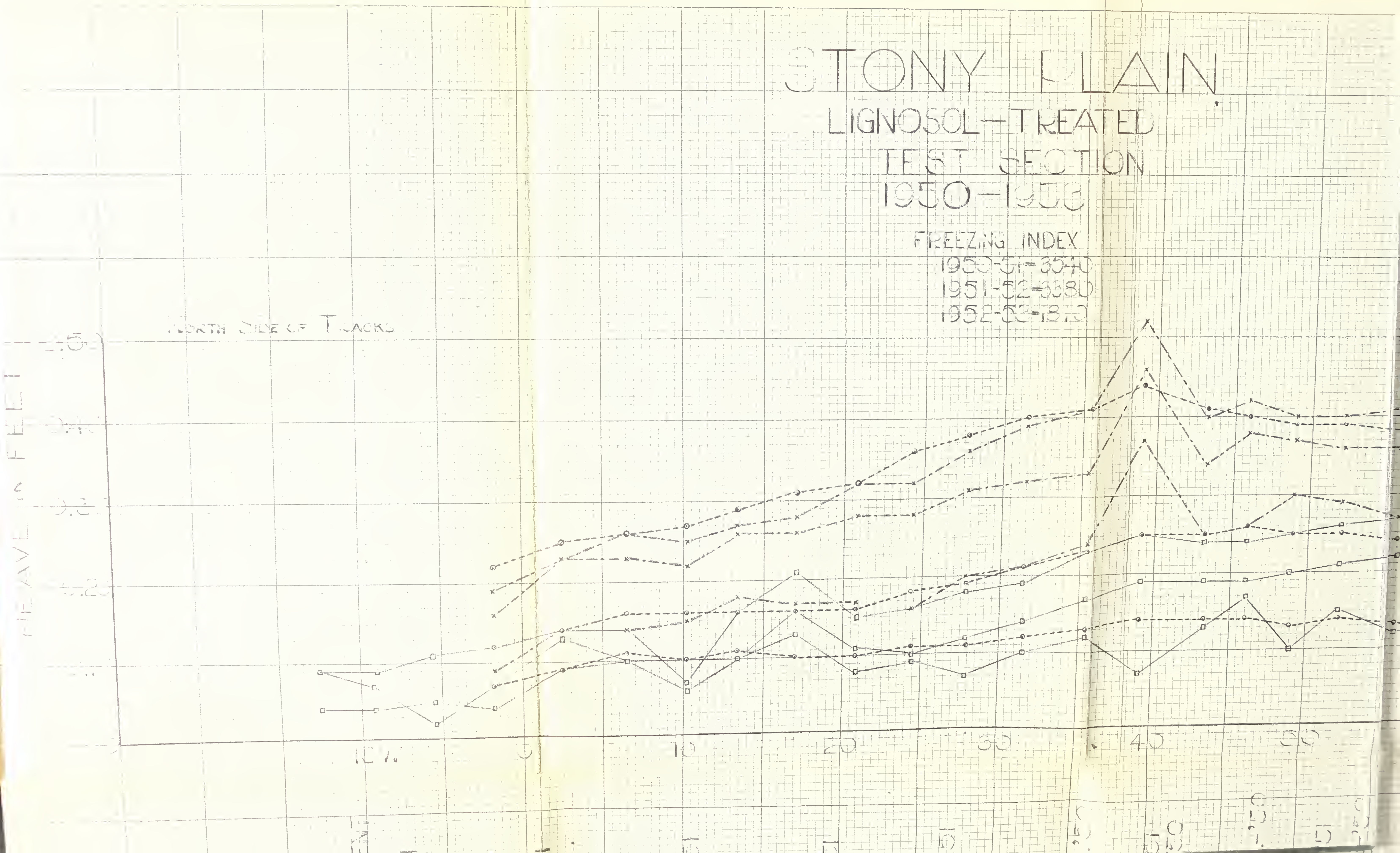


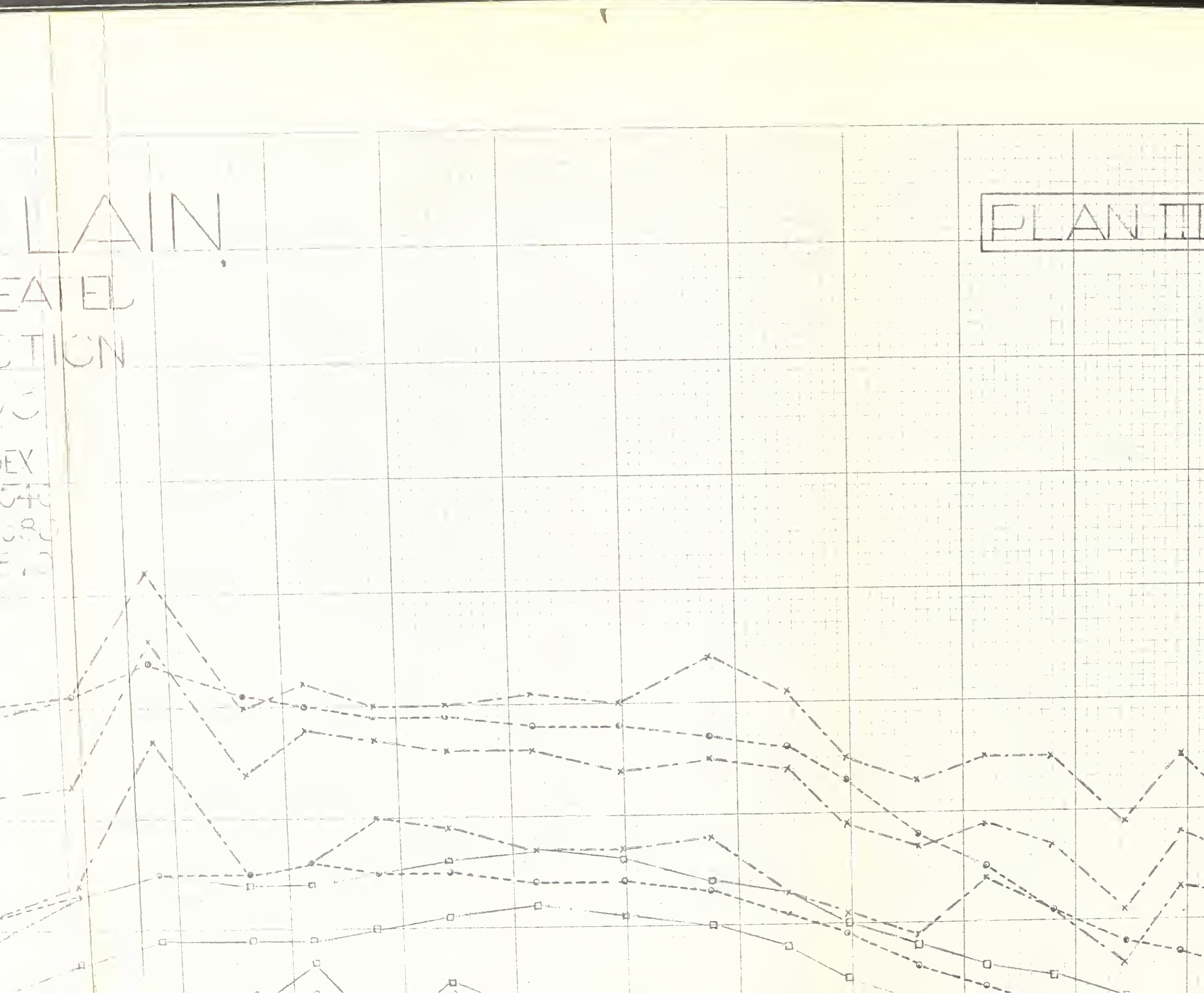
10W
10
20
30
40
50
EXCAVATED AND BACKFILLED WITH GRAVEL
ORIGINAL SUBGRADE MATERIAL
EXCAVATE
SOUTH SIDE OF TRACKS
0.20
0.10
0
HEAVE IN FEET
10W
0
10
20
30
40
50
60

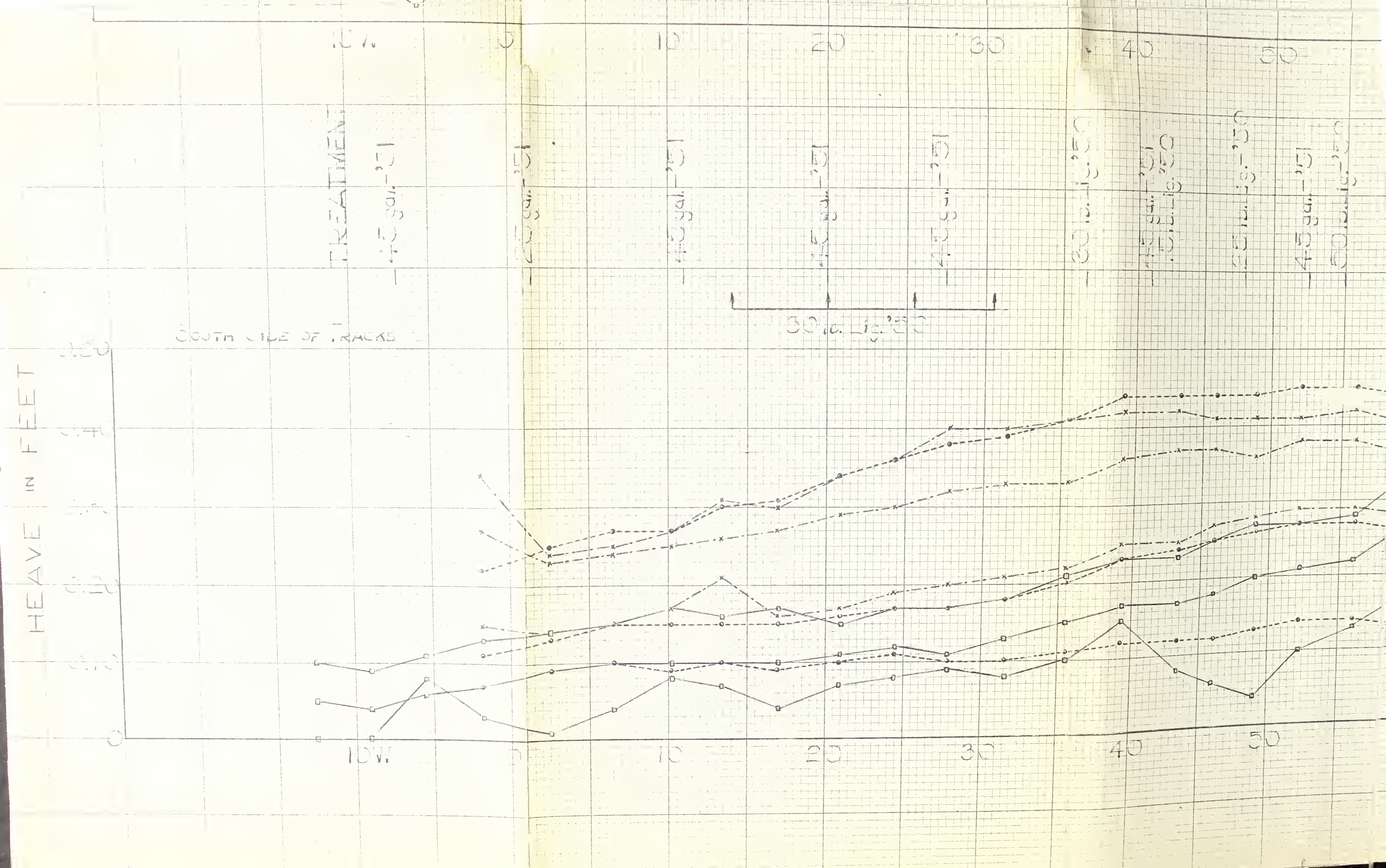


— EXCAVATED AND BACKFILLED WITH GRAVEL

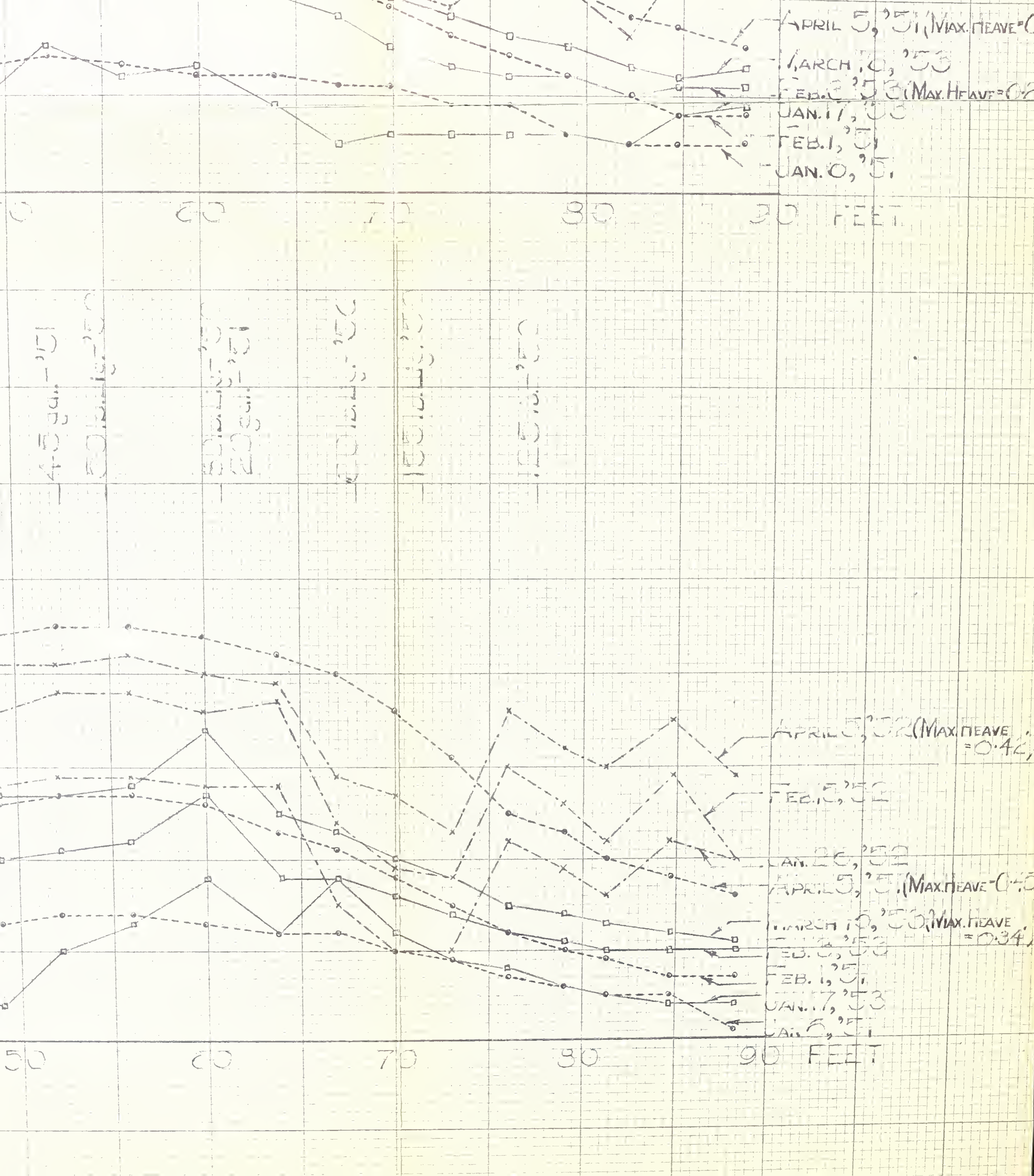



STONY PLAIN
LIGNOSOL—TREATED
TEST SECTION
1950-1953
FREEZING INDEX
1950-51=3540
1951-52=3380
1952-53=1870
NORTH SIDE OF TRACKS
HEAVE IN FEET
0.5
0.4
0.3
0.2
10W
0
10
20
30
40
50


LAIN
EATED
CTION
PLAN



TREATMENT
45 gal.-'51
45 gal.-'51
45 gal.-'51
45 gal.-'51
30 lb. Lig. '50
SOUTH SIDE OF TRACKS
HEAVE IN FEET
0
10W
0
10
20
30
40
50

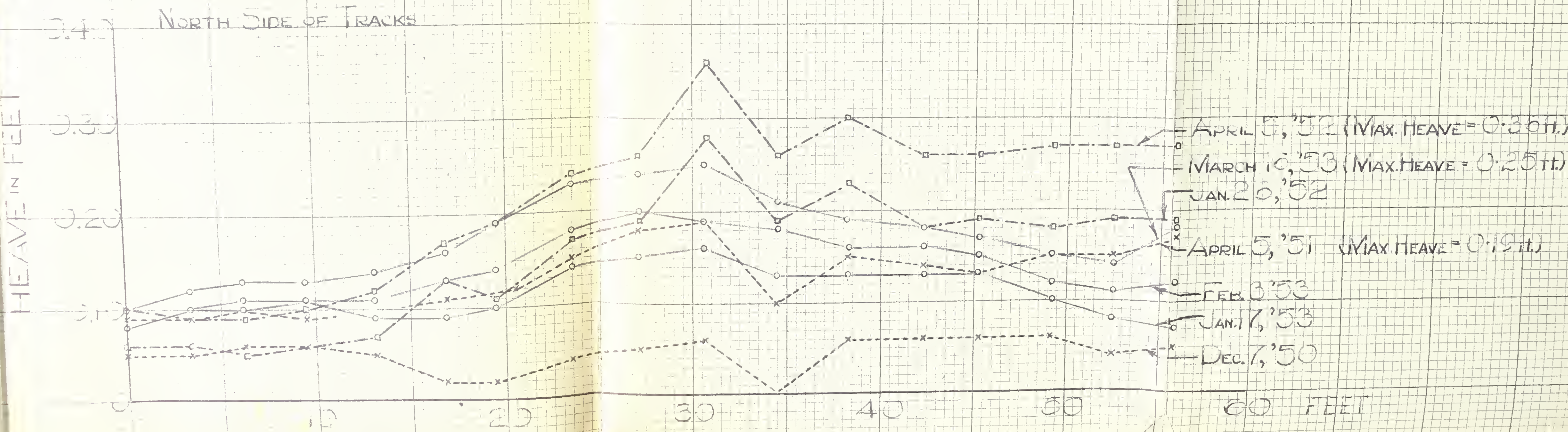


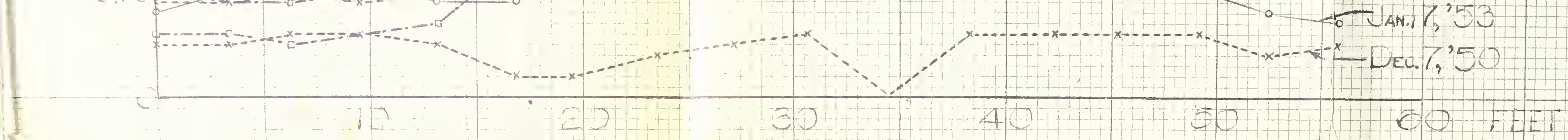
APRIL 5, '51 (MAX. HEAVE=0.44)
MARCH 6, '53
FEB. 3, '53 (MAX. HEAVE=0.22)
JAN. 17, '53
FEB. 1, '51
JAN. 6, '51
60
70
80
90 FEET
APRIL 5, '52 (MAX. HEAVE =0.42)
FEB. 5, '52
JAN. 26, '52
APRIL 5, '51 (MAX. HEAVE-0.45)
MARCH 6, '53 (MAX. HEAVE =0.34)
FEB. 3, '53
FEB. 1, '51
JAN. 17, '53
JAN. 6, '51
50
60
70
80
90 FEET

SPRUCE GROVE
LIGNOSOL — TREATED
TEST SECTION
1950-1953

PLAN IV

FREEZING INDEX
1950-51=3540
1951-52=3380
1952-53=1810




Jan. 7, '53
Dec. 7, '50
10
20
30
40
50
60 FEET

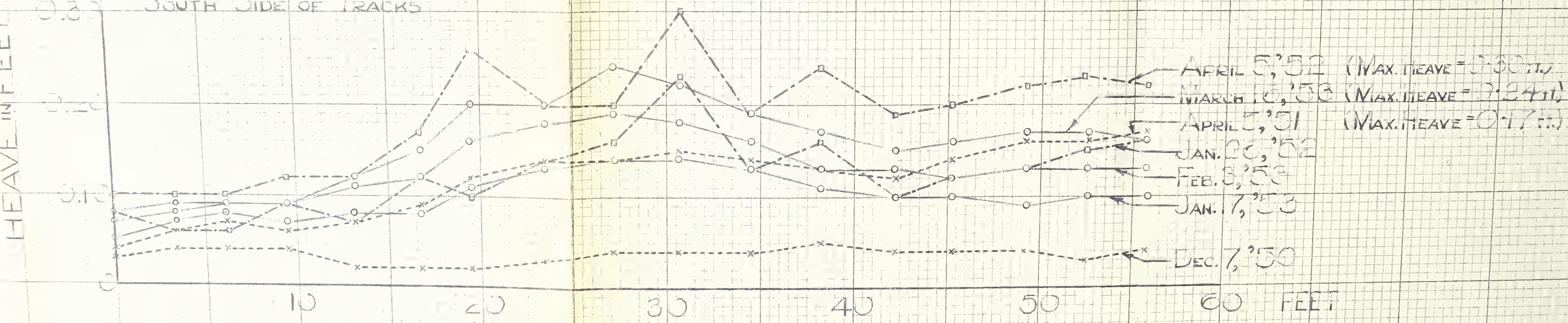

South Side of Tracks
Heave in Feet
0.20
0.10
0
April 5, '52
April 5, '51
Jan. 7, '53
Dec. 7, '50
10
20
30
40
50
60 FEET

Table XXVII shows that although the Freezing Index for the winter of 1952-53 was much lower than the two previous years, the average heave in the Fallis area was nearly the same as that of the previous two years. By the use of a ground temperature gauge at the University of Alberta, it was found that the frost line was between one and one and one-half feet below ground surface, as compared to five feet for the two previous years. The net result which was expected was that the heaving would be less in 1952-53 than before. Since the heaving was not appreciably less at Fallis, it was considered that this section had had the Lignosol partially leached out by the ground water movement in the spring and fall. (Rains affect only the top two feet or so, and would not be a factor in the washing out of the Lignosol, which is between four and five feet below the ground surface.)

Records were kept of the levels of two untreated heaving areas within 750 feet east of the treated section, shown on Plan I. The heaves here reached maximums of 0.41 feet and 0.53 feet for the west and east untreated sections respectively. These are possibly the magnitudes of heave which might have been expected at the treated section, but until further investigation of these three Fallis areas, it cannot be justifiably said that the Lignosol treatment of 1950-51 had been effective for two years only. On the other hand, it would be incorrect to state that the treatment at this area was effective for three years. However, the likelihood is that the effectiveness of the treatment has been partially lost.

Plan III shows the treatment and heaving records for the past three years at Stony Plain. The average heave was half of that which it had been each of the two previous winters. Due to a cyclic freezing and thawing in the late fall of 1952, the two top feet of soil became excessively wet, and although no moisture contents were taken, the soil could have held as much as

35% moisture, as was shown by Yurkiw. A frost penetration of two feet would produce a heave of 0.19 feet by the expansion of the interstitial water on freezing. The average heave in this area was only 0.16 feet and the maximum 0.34 feet. The probability is that the Lignosol layer at the 4-5 foot depth slowed down the rate of capillary rise of the water to the extent that very little of the water from below the treated layer ever reached the zone of freezing. Indeed, the maximum heaving of 0.34 feet could have occurred by the transfer of water from the soil between the 3- and 5-foot depths, to the zone of freezing. It is an accepted hypothesis that the ice lenses formed on freezing have an affinity for water and will draw the moisture out of adjacent soil.

As is shown on Plan IV, the average heaving at Spruce Grove was half that of 1950-51 and 1951-52.

TABLE XXVII. HEAVE COMPARISONS, 1950-51-52-53 - FIELD RESULTS

Section	Heave (ft.) 1950-51		Heave (ft.) 1951-52		Heave (ft.) 1952-53	
	Max.	Avg.	Max.	Avg.	Max.	Avg.
Fallis	0.16	0.07	0.17	0.12	0.18	0.10
Spruce Grove	0.19	0.13	0.36	0.20	0.25	0.17
Stony Plain	0.45	0.32	0.52	0.33	0.34	0.16
Freezing Index (Degree Days)	3540		3380		1810	

CONCLUSIONS

1. The field treatment was effective for two years. The third year the heaving was greater than was considered to be consistent with the previous records. The reason for the decrease in the effectiveness was probably due to the washing out of the Lignosol by ground water movement.

2. The Stony Plain treatment cannot be evaluated because of the possibility of the total heave being due to the pore water expansion on freezing.

3. The cost of Lignosol treatment is 5¢ per square foot per year, as compared to 60¢ per square foot per year for maintenance, based on full treatment every two years.

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APPENDIX

TABLE XXVIII.

UNIVERSITY of ALBERTA
DEP'T of CIVIL ENGINEERING
SOIL MECHANICS LABORATORY

CONSOLIDATION DATA

PROJECT	No ADMIXTURE
SITE	
SAMPLE	
LOCATION	
HOLE	DEPTH
TECHNICIAN	DATE

Ring Data

Ring No. B9
Weight gm's. 600.13
Thickness ins. 0.9
Diameter ins.
Area sq. cm's. 34.2

Machine Data

Machine No.
Multiplication Factor
Wt. Block + Stone + Ball gm's.
Description of Sample

Consolidation Sample Weights

Wt. Tare + Ring + Soil + Water (End) gms. 751.70
Wt. Tare + Ring + Soil (End) gms. 735.28
Wt. Tare (Tare No. 1 24) gms 34.77
Wt. Ring + Soil + Water (End) gms 716.93
Wt Ring + Soil + Water (Start) gms 737.48
Wt Ring + Soil gms. 700.51
Wt. Soil gms 100.38
Water (End) = 16.42 gms. = 16.4 %
Water (Start) = 36.97 gms. = 36.9 %

Date, Time Load, Dial Remarks	Date, Time Load, Dial Remarks	Date, Time Load, Dial Remarks	Date, Time Load, Dial Remarks	Date, Time Load, Dial Remarks	Date, Time Load, Dial Remarks	Date, Time Load, Dial Remarks
MAR. 2	8 8989	115 8621	30 8096	1430 7213	30 6775	340 6210
09:00	16 75	214 599	1 88	2980 08	1 64	435 6205
20gm.	30 49	301 92	2 71	4350 7205	2 50	1420 6198
0 9148	63 32	458 90	4 51	MAR. 16	4 28	
6 20	120 21	1415 8587	9 15	08:55	8 6696	
10 18	242 06	MAR. 10	16 7981	1500gm	15 62	
15 16	346 02	08:39	30 37	6 7152	32 10	
30 12	472 8880	200gm.	63 7878	10 45	70 6561	
1 08	1450 42	6 8542	142 10	15 40	122 38	
WATER	1730 39	10 39	216 788	30 31	240 20	
2 08	2880 32	15 36	325 64	1 20	330 11	
4 00	3860 28	30 29	457 44	2 05	477 06	
9 04	4220 25	1 17	1410 20	4 7036	1461 6491	
15 9095	5760 20	2 8496	2880 7702	8 55	MAR. 18	
20 83	8640 16	4 77	MAR. 13	25 6986	09:06	
60 74	MAR. 9	8 48	08:35	45 48	6000gm.	
120 65	08:59	18 8400	800gm.	82 15	6 6428	
160 63	100gm.	30 8355	6 7613	115 6901	10 23	
240 62	6 8775	60 293	10 08	120 6875	15 49	
450 61	10 71	110 57	15 01	180 85	30 41	
1410 9059	15 67	190 29	30 7588	230 75	1 30	
MAR. 3	30 62	330 8200	1 72	387 62	2 17	
08:34	1 56	478 94	2 51	465 60	6 6382	
30gm.	2 48	1440 8104	4 26	1420 6849	8 73	
6 9019	4 32	MAR. 11	8 7483	MAR. 17	24 6281	
10 18	8 11	09:00	15 32	08:38	40 72	
15 17	15 8685	400gm.	30 7366	3000gm.	47 50	
30 15	31 47	6 8115	70 7238	6 6792	71 29	
1 12		10 11	113 24	10 89	124 [illegible]	
2 05		15 08	215 32	15 85	178 21	
4 01			280 26			
			470 19			

UNIVERSITY of ALBERTA DEPT. of CIVIL ENGINEERING SOIL MECHANICS LABORATORY CONSOLIDATION RESULTS	
	PROJECT No ADMIXTURE
	SITE
	SAMPLE
	LOCATION
	HOLE DEPTH
	TECHNICIAN DATE

Specific Gravity of Soil Solids G_s = 2·59 Height of Soil Solids H_s = 0.447 ins.

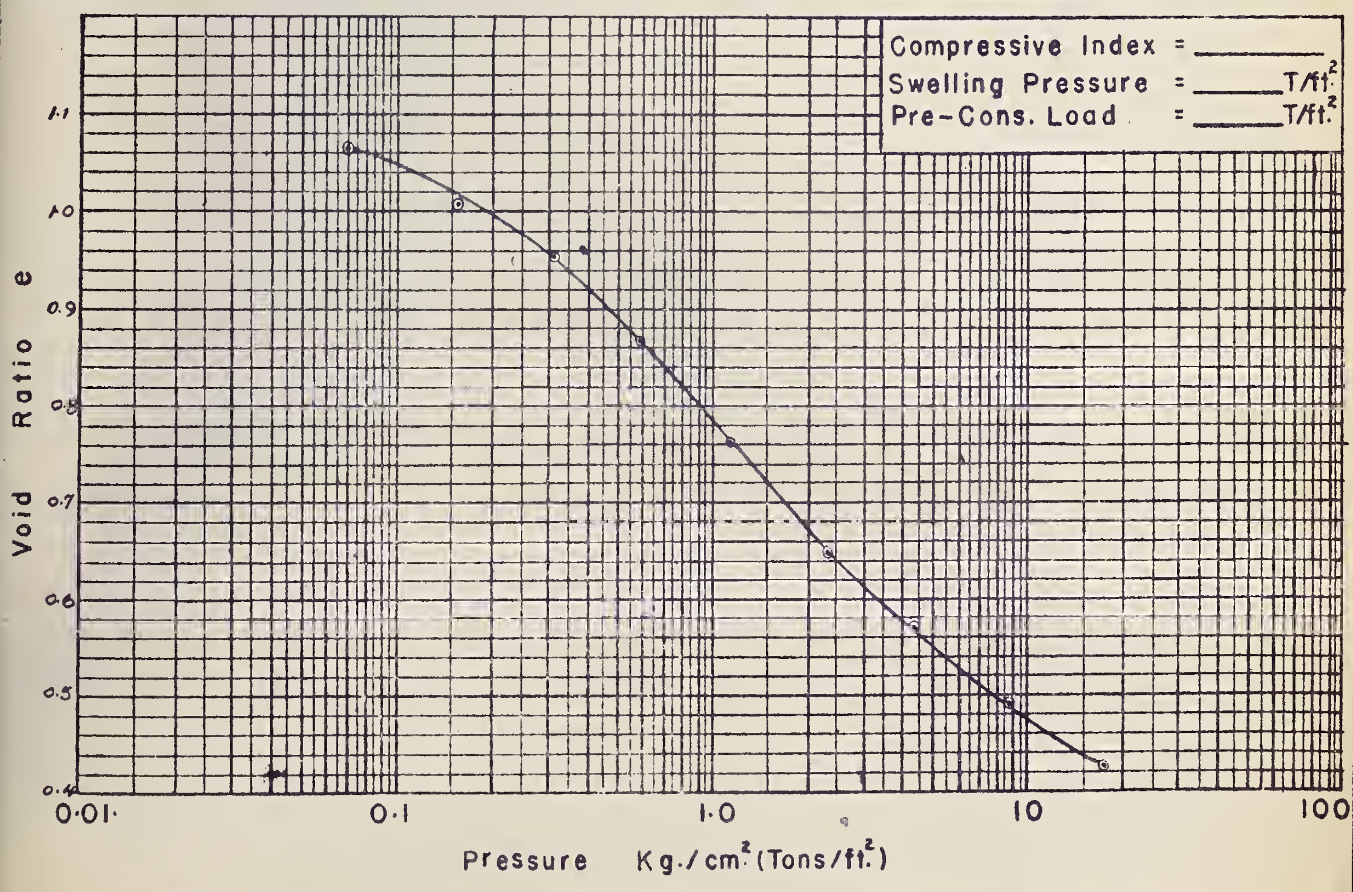
Void Ratio e (End) = 0·424

Void Ratio e(Start) = 1 084

Void Ratio e (Start Dimensions) = 0·988

$e(End) = W\%(End) \times G_s$ $\quad H_s = \left(\frac{Wt \cdot Soil}{G_s \times Area \times 2\cdot54}\right)$ ins. $\quad e$ = previous $e \pm \frac{Def'l.}{H_s}$

Time Interval	Load on Pan (gms)	Corr. Dial Reading (ins.)	Deflection (ins.)	Deflection / H_s	Void Ratio e	Pressure Kg/cm² = T/ft²
	0	9148			1.084	
	20	9059	0.0089	0.0199	1.064	0.070
	50	8816	·0243	·0543	1.009	0.158
	100	8587	·0229	·0512	0.958	0.304
	200	8184	·0403	·0902	0.868	0.596
	400	7702	·0482	·1075	0.760	1.18
	800	7205	·0497	·1112	0.649	2.34
	1500	6849	·0356	·0796	0.570	4.39
	3000	6491	·0358	·0801	0.490	8.77
	6000	6198	·0293	·0655	0.424	17.5



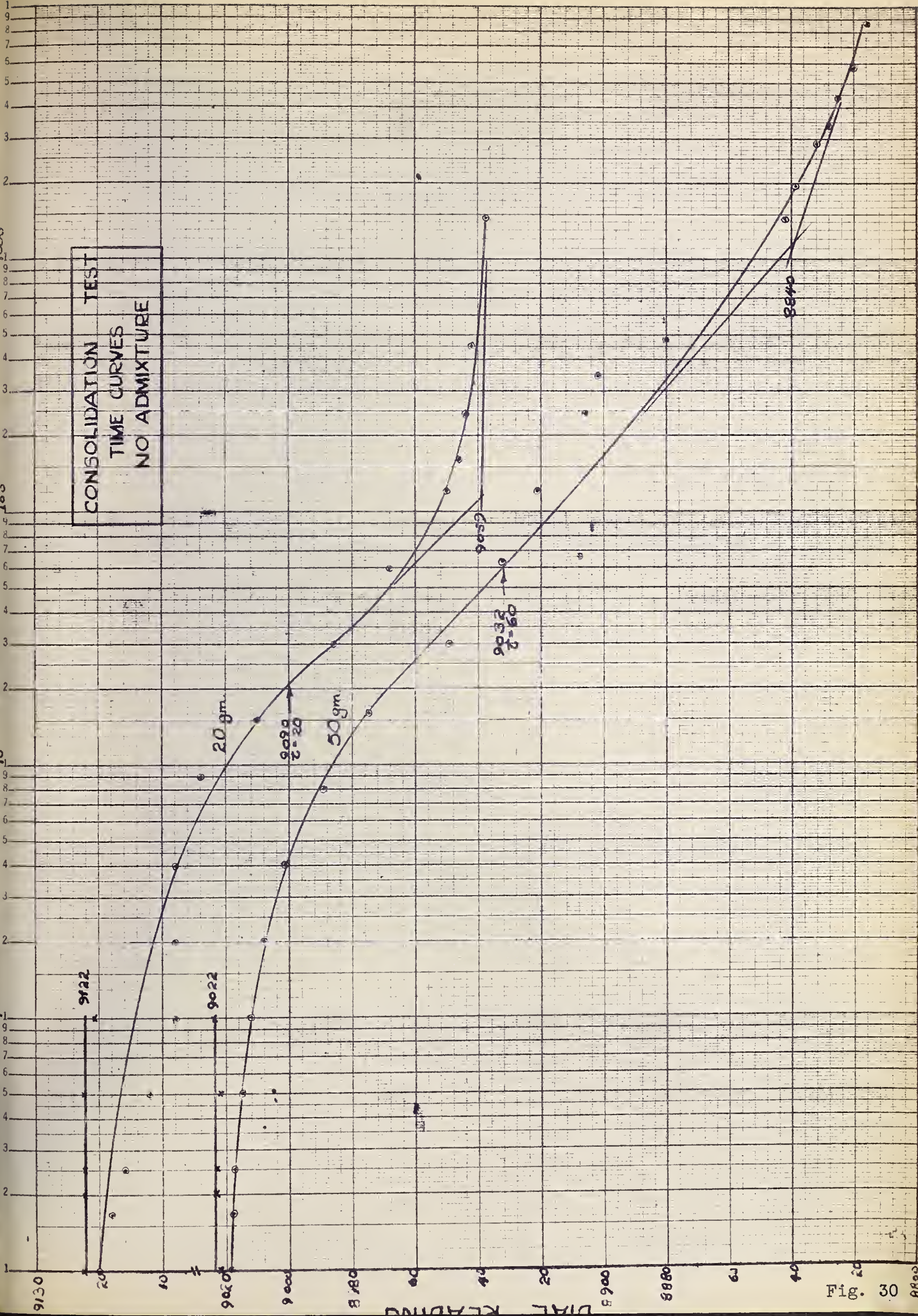

CONSOLIDATION TEST
TIME CURVES
NO ADMIXTURE
20 gm
50 gm
9090
t=20
9032
t=60
9059
8840
9122
9022
9130
9020
9000
8980
8960
8940
8920
8900
8880
8860
8840
8820
8800

Fig. 30

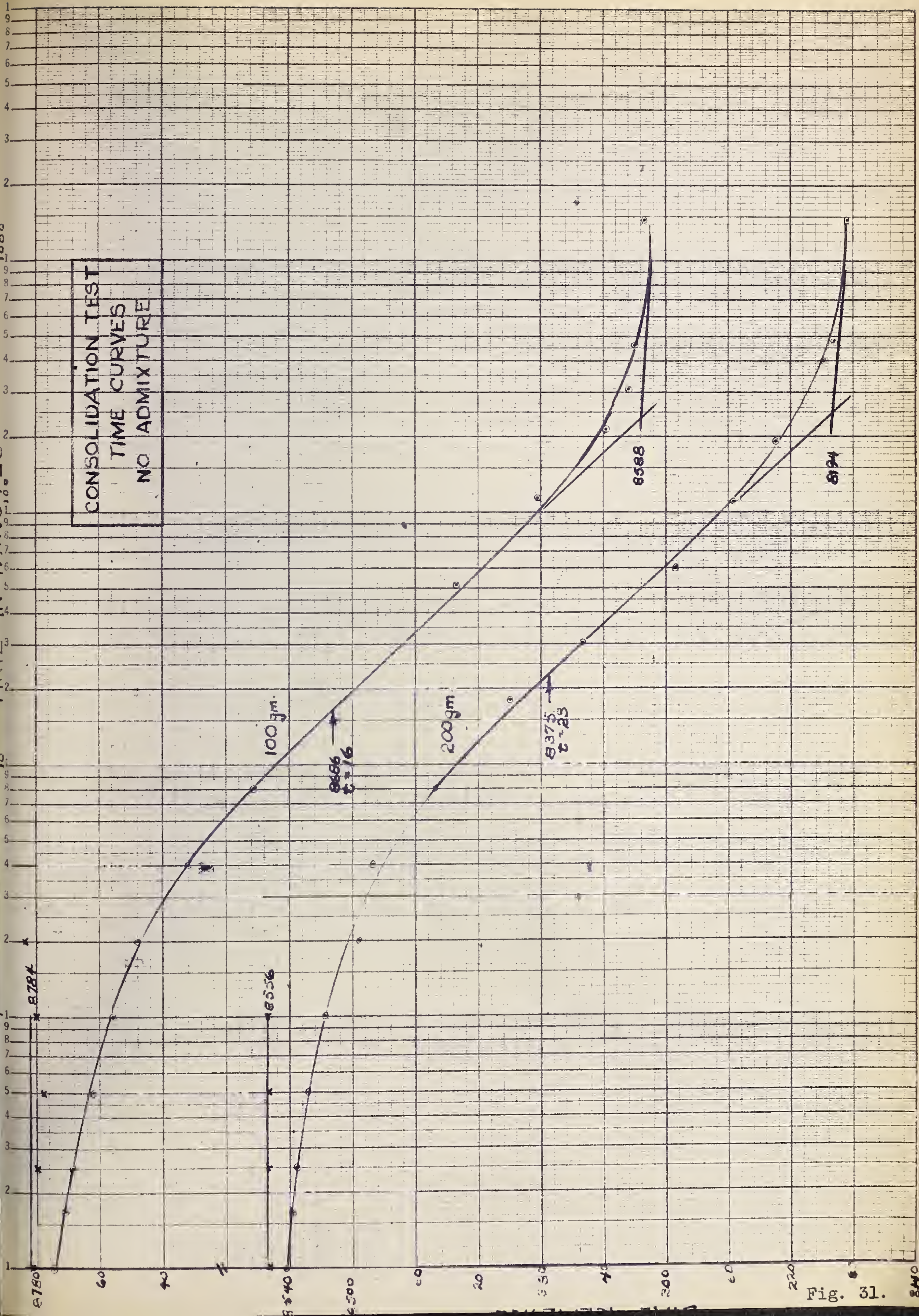
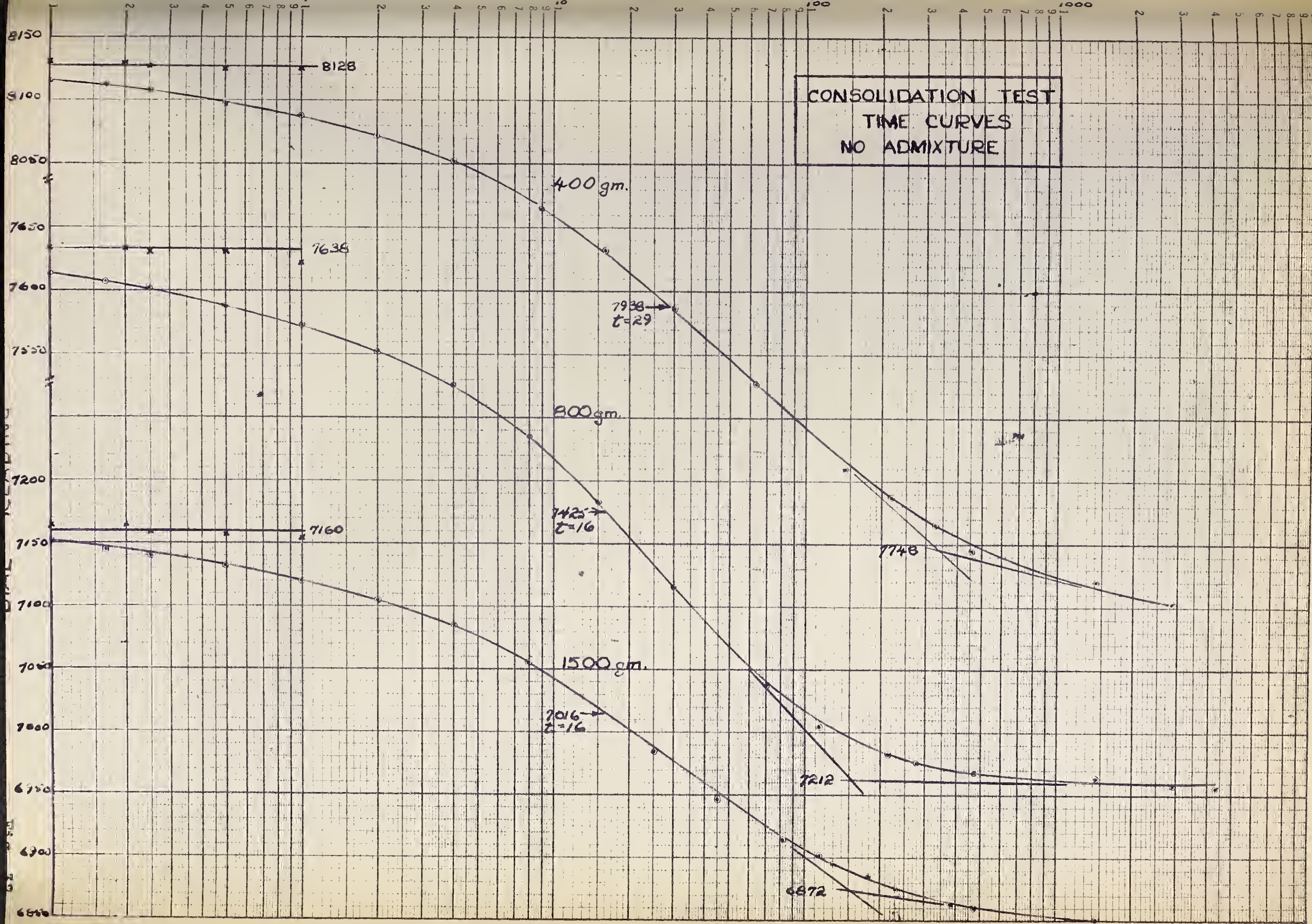

CONSOLIDATION TEST
TIME CURVES
NO ADMIXTURE
TIME IN MINUTES
100gm.
200gm
8588
8784
8556

Fig. 31.


CONSOLIDATION TEST
TIME CURVES
NO ADMIXTURE
400 gm.
800 gm.
1500 gm.
8128
7638
7160
7748
7212
6872
7938 t=29
7425 t=16
7016 t=16

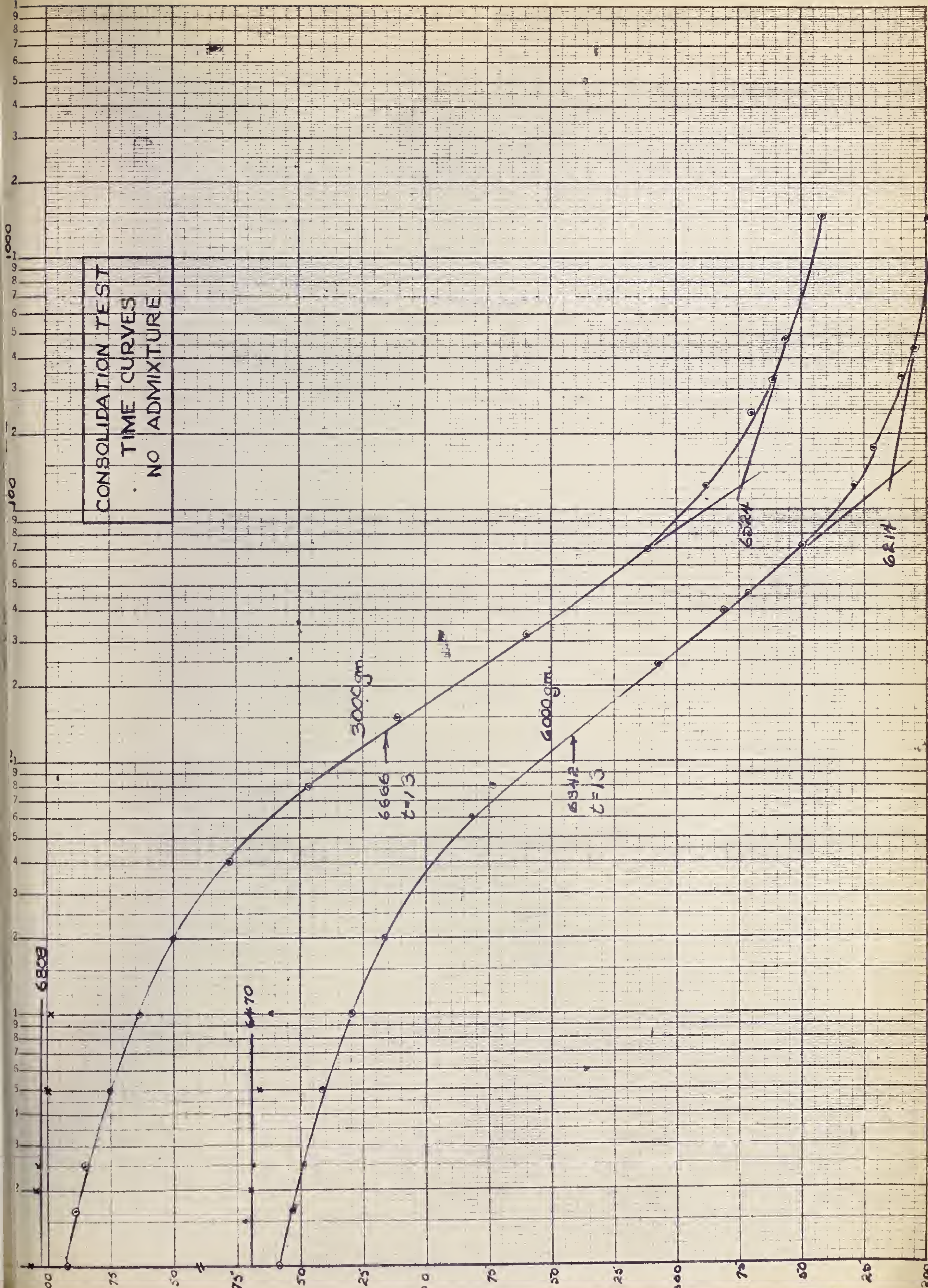

CONSOLIDATION TEST
TIME CURVES
NO ADMIXTURE
3000 gm.
6000 gm.
6666
t=13
6342
t=13
6524
6214
6808
6470

Fig. 33.

TABLE XXIX.

UNIVERSITY of ALBERTA DEP'T of CIVIL ENGINEERING SOIL MECHANICS LABORATORY CONSOLIDATION DATA	
	PROJECT NO ADMIXTURE
	SITE
	SAMPLE
	LOCATION
	HOLE DEPTH
	TECHNICIAN DATE

Ring Data	Consolidation Sample Weights
Ring No. B12	Wt. Tare + Ring + Soil + Water (End) gms. 768.62
Weight gm's. 598.20	Wt. Tare + Ring + Soil (End) gms. 749.70
Thickness ins. 0.9	Wt. Tare (Tare No. T18) gms 32.38
Diameter ins.	Wt. Ring + Soil + Water (End) gms. 736.24
Area sq. cm's 34.2	Wt. Ring + Soil + Water (Start) gms. 749.50
Machine Data	Wt. Ring + Soil gms. 717.32
Machine No. 5	Wt. Soil gms 119.12
Multiplication Factor 150	Water (End) = 18.92 gms. = 15.9 %
Wt. Block + Stone + Ball gm's.	Water (Start) = 32.18 gms = 27.0 %

Description of Sample Initial Wet Density = 120.8 #/ft.³
Initial Dry Density = 95.1 #/ft.³

Date, Time Load, Dial Remarks	Date, Time Load, Dial Remarks	Date, Time Load, Dial Remarks	Date, Time Load, Dial Remarks	Date, Time Load, Dial Remarks	Date, Time Load, Dial Remarks	Date, Time Load, Dial Remarks
DEC. 10	30 6727	7100 6658	2 6378	300 5800	1 5343	15 4938
1423	105 23	DEC. 17	4 60	420 5790	2 20	30 02
20 gm	150 21	09:07	6 52	1440 5772	4 13	50 4871
C 6960	240 20	200 gm.	8 43	DEC. 20	8 5295	115 18
6 46	340 19	3 6620	15 24	08:51	13 74	360 4775
10 45	450 18	6 18	23 17	1500 gm.	30 28	1560 58
15 45	1410 6717	10 15	43 6278	6 5720	55 5190	4320 4752
30 45	DEC. 12	15 13	75 45	10 12	120 32	
1 44	08:18	30 11	150 07	15 08	165 15	
2 43	100 gm.	1 08	290 6178	30 5098	250 5100	
WATER	3 6795	2 04	390 71	1 88	345 5090	
4 47	6 92	4 6598	1440 6154	2 78	455 85	
8 48	10 90	8 92	DEC. 19	4 62	1440 72	
15 48	15 89	15 82	09:09	8 42	1890 71	
30 49	30 86	30 67	800 gm.	15 18	2880 5066	
120 48	1 82	70 44	3 6085	30 5586	DEC. 24	
980 48	2 77	120 26	6 80	60 45	09:00	
DEC. 11	4 71	240 06	10 75	100 02	6000 gm.	
08:49	8 65	375 6498	15 70	180 5470	6 5020	
50 gm.	16 60	425 96	30 60	300 50	10 28	
5 6941	30 51	1440 6481	1 49	1600 29	15 25	
10 40	52 42	DEC. 18	2 38	2850 5422	30 18	
15 39	120 24	09:09	4 23	DEC. 22	1 12	
30 38	190 12	400 gm.	8 08	08:50	2 02	
1 38	300 04	6 6415	15 5984	3000 gm.	4 4985	
2 35	480 6697	10 08	30 47	6 5370	8 60	
4 34	1470 79	15 03	55 24	10 65		
8 32	4350 61	80 6397	120 5847	15 60		
17 31	5700 6658	1 88	210 5804	30 53		
30 29						

TABLE XXIX(a).

UNIVERSITY of ALBERTA DEPT. of CIVIL ENGINEERING SOIL MECHANICS LABORATORY CONSOLIDATION RESULTS	PROJECT NO ADMIXTURE SITE SAMPLE LOCATION HOLE DEPTH TECHNICIAN DATE

Specific Gravity of Soil Solids G_s = 2.58 Height of Soil Solids H_s = 0.5[illegible]2 ins.

Void Ratio e (End) = 0.410

Void Ratio e (Start) = 0.823

Void Ratio e (Start Dimensions) = 0.692

e (End) = W%(End) x G_s $H_s = \left(\frac{\text{Wt. Soil}}{G_s \times \text{Area} \times 2.54}\right)$ ins. e = previous e $\pm \frac{\text{Def'l.}}{H_s}$

Time Interval	Load on Pan (gms)	Corr. Dial Reading (ins.)	Deflection (ins.)	$\frac{\text{Deflection}}{H_s}$	Void Ratio e	Pressure Kg/cm² = T/ft²
	0	6960			0.823	
	20	6948	0.0012	0.0022	0.821	0.070
	50	6917	.0031	.0058	0.815	0.158
	100	6658	.0259	.0484	0.767	0.304
	200	6481	.0177	.0331	0.733	[illegible]26
	400	6154	.0327	.0611	0.672	1.18
	800	5772	.0382	.0713	0.601	2.34
	1500	5422	.0350	.0655	0.555	4.39
	3000	5068	.0354	.0662	0.487	8.77
	6000	4752	.0316	.0591	0.410	17.5

Compressive Index = _____

Swelling Pressure = _____ T/ft²

Pre-Cons. Load = _____ T/ft²

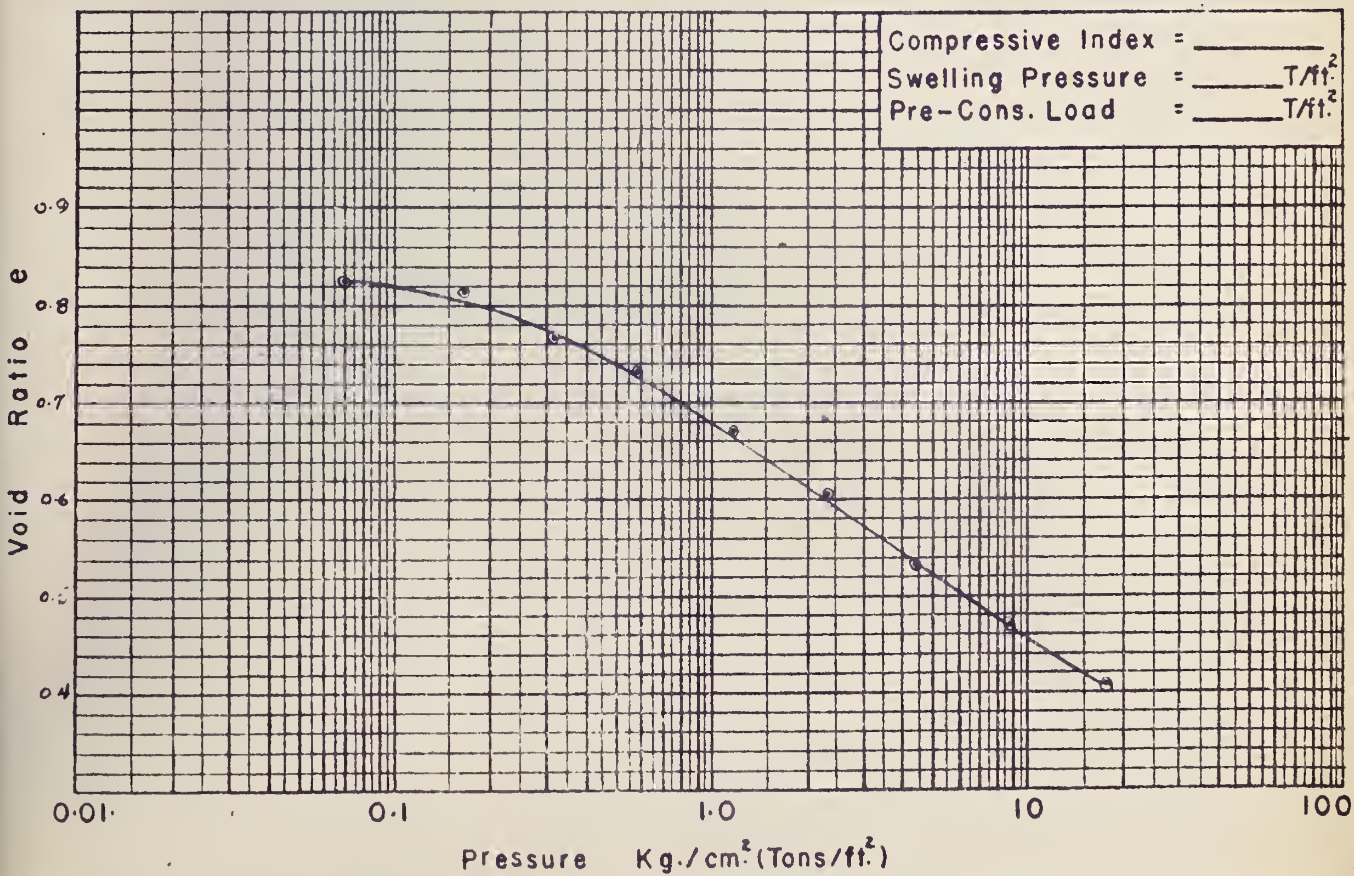


TABLE XXX.

UNIVERSITY of ALBERTA DEP'T of CIVIL ENGINEERING SOIL MECHANICS LABORATORY **CONSOLIDATION DATA**	PROJECT AEROSOL T.E.F. 16 SITE Solution Strength = 12.6% SAMPLE Viscosity = 2.50 ct.k. (Room) LOCATION HOLE DEPTH TECHNICIAN DATE

Ring Data		Consolidation Sample Weights	
Ring No.	A-2	Wt. Tare + Ring + Soil + Water (End) gms	650.52
Weight gm's.	473.5	Wt. Tare + Ring + Soil (End) gms.	638.10
Thickness ins.	0.68	Wt. Tare (Tare No V18) gms	74.82
Diameter ins.		Wt. Ring + Soil + Water (End) gms	575.70
Area sq. cm's	342	Wt. Ring + Soil + Water (Start) gms	586.18
Machine Data		Wt. Ring + Soil gms	563.28
Machine No.		Wt. Soil gms	89.77
Multiplication Factor		Water (End) = 12.42 gms. =	13.85 %
Wt. Block + Stone + Ball gm's.		Water (Start) = 22.90 gms =	25.5 %
Description of Sample			

Date, Time Load, Dial Remarks	Date, Time Load, Dial Remarks	Date, Time Load, Dial Remarks	Date, Time Load, Dial Remarks	Date, Time Load, Dial Remarks	Date, Time Load, Dial Remarks	Date, Time Load, Dial Remarks
FEB. 11	23 7449	FEB. 17	126 6881	2 6505	FEB. 24	
09:49	42 45	08:48	212 71	4 6488	6000 gm.	
20gm.	96 42	200gm.	265 68	8 62	09:17	
0 7488	125 39	6 7253	420 59	16 30	6 5956	
6 74	229 35	10 51	1430 6848	30 6398	10 52	
10 74	255 33	15 48	FEB. 19	60 65	15 49	
15 74	400 32	30 46	09:08	129 33	30 43	
30 74	472 32	1 38	800 gm.	215 18	1 34	
1 73	1440 23	2 29	6 6918	330 06	2 22	
WATER	1860 22	4 19	10 10	450 6300	4 08	
2 78	2880 16	8 08	15 02	1432 6280	8 5890	
4 79	5760 7417	15 7191	30 6794	4320 6261	16 60	
9 81	FEB 16	30 70	1 84	FEB. 23	30 28	
15 84	09:00	58 52	2 79	09:09	60 5797	
38 88	100 gm	120 28	4 47	3000 gm	120 70	
62 89	6 7394	270 7099	8 32	6 6215	193 59	
120 88	10 89	460 89	15 03	10 12	378 48	
215 88	15 86	1440 7080	29 6675	15 08	443 45	
400 87	30 82	FEB. 18	50 53	30 02	1415 25	
1370 7486	1 77	09:06	78 38	1 6191	1835 20	
FEB. 12	2 72	400 gm.	120 25	2 79	2255 5714	
08:56	4 65	6 7039	252 09	4 62		
50gm	8 54	10 32	420 6600	9 40		
6 7469	15 46	15 28	1437 6[illegible]	16 15		
10 67	30 35	30 17	FEB. 20	33 6078		
15 66	61 23	1 10	09:03	71 45		
30 65	137 04	2 6944	1500 gm.	123 24		
1 63	250 7291	6 72	6 6551	300 10		
2 61	470 85	8 62	10 45	458 05		
4 58	1420 7270	15 41	15 41	1430 5988		
17 51		30 19	30 31			
		60 6899	1 19			

UNIVERSITY of ALBERTA
DEPT. of CIVIL ENGINEERING
SOIL MECHANICS LABORATORY
CONSOLIDATION RESULTS

PROJECT Albrosol TEF 16	
SITE	
SAMPLE	
LOCATION	
HOLE	DEPTH
TECHNICIAN	DATE

Specific Gravity of Soil Solids G_s = 2.58 Height of Soil Solids H_s = 0.400 ins.

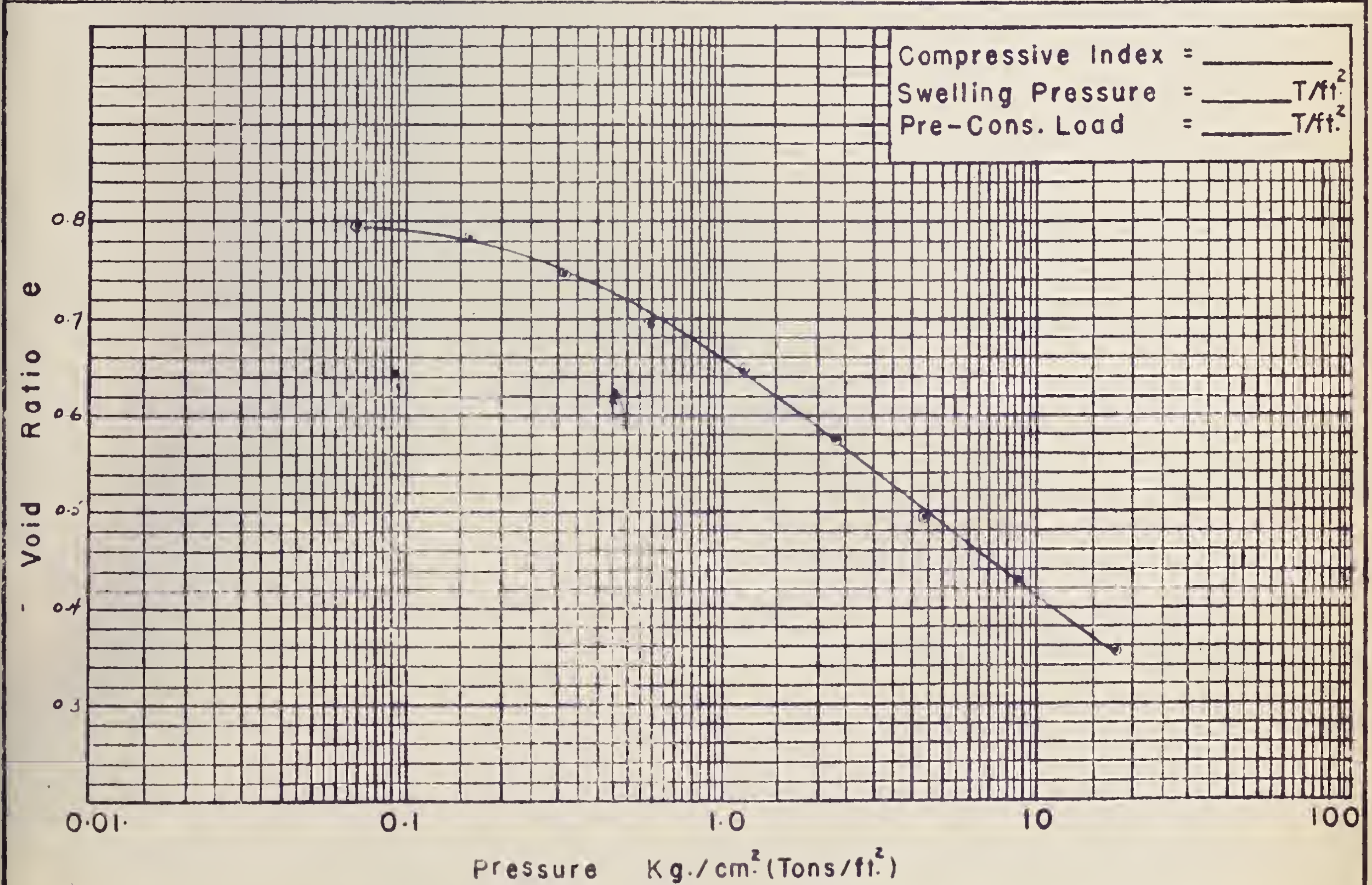
Void Ratio e (End) = 0.357

Void Ratio e(Start) = 0.799

Void Ratio e (Start Dimensions) = 0.700

$e(End) = W\%(End) \times G_s$ $\qquad H_s = \left(\frac{\text{Wt. Soil}}{G_s \times \text{Area} \times 2.54}\right)\text{ins.}$ $\qquad e = \text{previous } e \pm \frac{\text{Def'l.}}{H_s}$

Time Interval	Load on Pan (gms)	Corr. Dial Reading (ins.)	Deflection (ins.)	Deflection / H_s	Void Ratio e	Pressure $Kg/cm^2 = T/ft^2$
	0	7488			0.791	
	20	7486	0.0002	0.0005	0.798	0.070
	50	7417	.0069	.0173	0.781	0.158
	100	7278	.0139	.0348	0.746	0.304
	200	7080	.0198	.0473	0.699	0.596
	400	6848	.0232	.0581	0.641	1.18
	800	6592	.0226	.0640	0.577	2.34
	1600	6261	.0331	.0828	0.494	4.39
	3000	5988	.0273	.0683	0.426	8.77
	6000	5714	.0274	.0685	0.357	17.5



UNIVERSITY of ALBERTA
DEP'T of CIVIL ENGINEERING
SOIL MECHANICS LABORATORY

CONSOLIDATION DATA

PROJECT	AERODOL AY
SITE	Solution Strength = 17.6 %
SAMPLE	Viscosity = 1.87 cstk. (Room)
LOCATION	
HOLE	DEPTH
TECHNICIAN	DATE

Ring Data

Ring No. A 3
Weight gm's. 463.55
Thickness ins. 0.68
Diameter ins.
Area sq. cm's 34.2

Machine Data

Machine No. 2
Multiplication Factor 100
Wt. Block + Stone + Ball gm's.

Consolidation Sample Weights

Wt. Tare + Ring + Soil + Water (End) gms. 597.22
Wt. Tare + Ring + Soil (End) gms. 583.53
Wt. Tare (Tare No 11) gms 83.93
Wt. Ring + Soil + Water (End) gms. 563.29
Wt. Ring + Soil + Water (Start) gms. 574.02
Wt. Ring + Soil gms. 549.60
Wt. Soil gms 86.05
Water (End) = 13.69 gms. = 15.9 %
Water (Start) = 24.42 gms = 28.4 %

Description of Sample

Date, Time Load, Dial Remarks	Date, Time Load, Dial Remarks	Date, Time Load, Dial Remarks	Date, Time Load, Dial Remarks	Date, Time Load, Dial Remarks	Date, Time Load, Dial Remarks	Date, Time Load, Dial Remarks
JAN. 26	15 9610	470 9460	2870 9234	27 8812	15 8320	
10:11	30 08	1430 9449	FEB. 11	90 8763	30 16	
20gm.	60 07	1550 46	09:07	120 4[illegible]	1 08	
0 9650	135 04	2880 38	400gm.	226 13	2 02	
6 34	230 03	4310 33	6 8628	240 12	4 8289	
10 33	430 02	4710 31	10 22	385 02	8 73	
15 32	1425 9598	5760 28	15 18	467 8612	15 55	
30 32	1855 92	7200 21	30 11	1440 8692	30 15	
1 31	2865 78	8470 21	1 03	FEB. 13	54 8192	
WATER	3260 75	10,000 9421	2 8593	09:03	130 42	
2 31	4320 61	FEB. 9	4 92	1500gm	250 15	
4 31	4740 68	08:58	8 73	6 8628	468 05	
8 31	5760 68	200gm.	14 65	10 22	1420 8103	
15 30	8640 9561	6 9389	30 55	15 1[illegible]	FEB. 17	
30 30	FEB. 2	10 86	68 8463	30 11	08:58	
60 30	09:10	15 83	130 32	1 03	6000gm.	
180 30	100gm.	30 77	147 23	2 8593	6 8073	
400 30	6 9536	1 70	250 05	4 92	10 70	
1380 9630	10 34	2 65	420 8398	8 73	15 68	
JAN. 27	15 32	4 56	1440 83	14 [illegible]3	30 62	
09:25	30 28	8 46	4320 8380	30 05	1 58	
50gm.	1 24	15 32	FEB. 12	68 8463	2 52	
6 9618	2 19	30 20	09:02	130 32	4 41	
10 17	5 12	55 02	800gm.	147 23	9 21	
15 16	8 08	115 9282	6 8932	250 05	15 02	
30 15	15 02	215 64	10 27	420 8398	30 7975	
1 14	30 9495	430 50	15 20	1440 53	60 38	
2 13	48 89	1440 36	30 12	4320 8380	115 01	
4 12	121 75	1870 34	1 04	FEB. 16	260 7862	
10 11	275 67		2 8897	09:06	430 52	
			6 79	3000gm	1435 7840	
			15 72	6 8330		
				10 25		

UNIVERSITY of ALBERTA DEPT. of CIVIL ENGINEERING SOIL MECHANICS LABORATORY **CONSOLIDATION RESULTS**	PROJECT AEROSOL A.Y. SITE SAMPLE LOCATION HOLE DEPTH TECHNICIAN DATE

Specific Gravity of Soil Solids G_s = 2.58 Height of Soil Solids H_s = 0.384 ins.

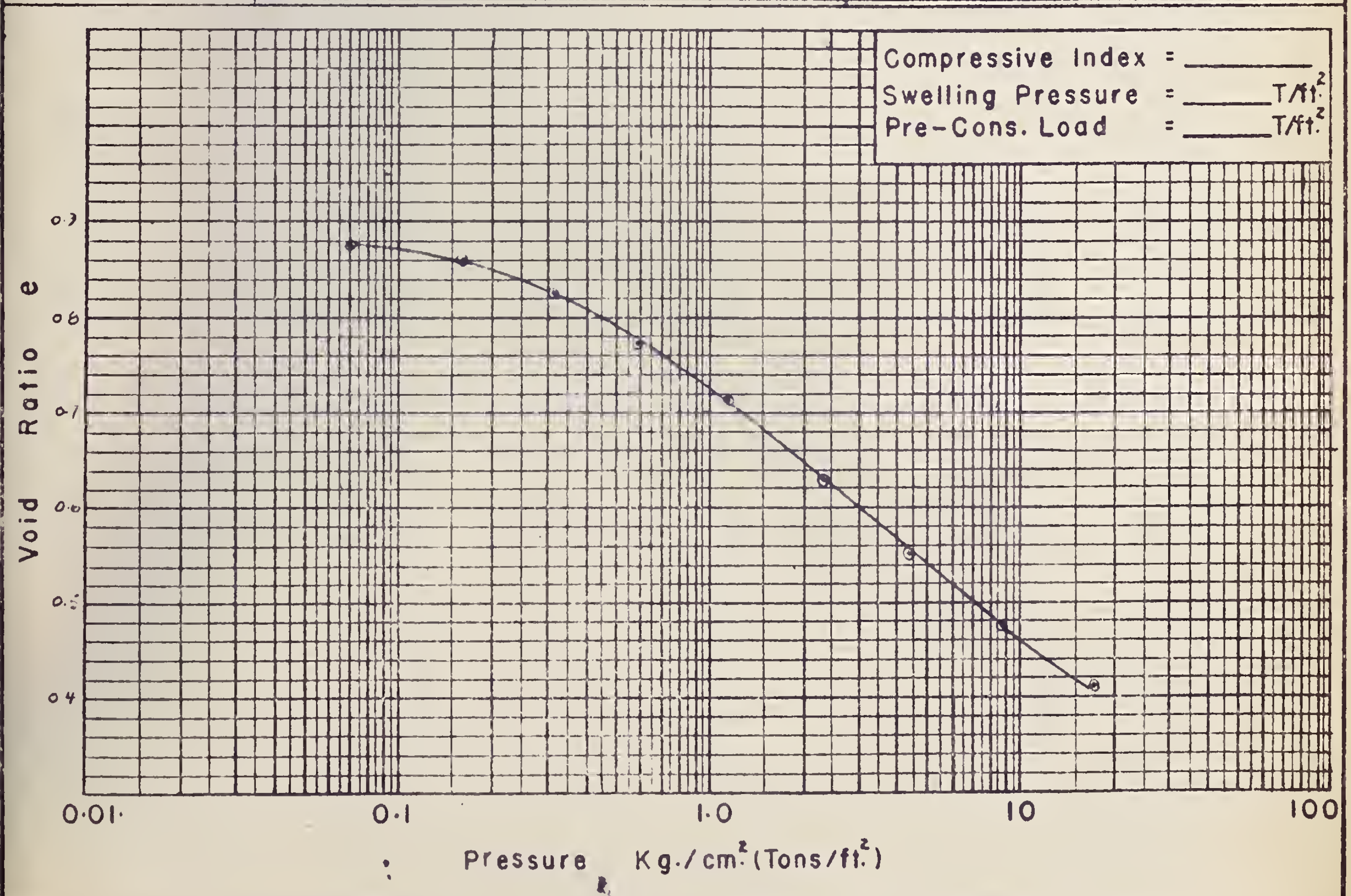
Void Ratio e (End) = 0.410

Void Ratio e (Start) = 0.883

Void Ratio e (Start Dimensions) = 0.771

$e(End) = W\%(End) \times G_s$ $H_s = \left(\frac{Wt. Soil}{G_s \times Area \times 2.54}\right)$ ins. $e = \text{previous } e \pm \frac{Def'l.}{H_s}$

Time Interval	Load on Pan (gms)	Corr. Dial Reading (ins).	Deflection (ins.)	$\frac{Deflection}{H_s}$	Void Ratio e	Pressure $Kg/cm^2 = T/ft^2$
	0	9650			0.883	
	20	9630	0.0020	0.0052	0.878	0.070
	50	9561	0.0069	.0180	0.860	0.1[illegible]
	100	9421	.0140	.0366	0.823	0.304
	200	9234	.0187	.0489	0.774	0.596
	400	9011	.0223	.0583	0.716	1.18
	800	8682	.0329	.0860	0.630	2.34
	1200	8380	.0302	.0789	0.551	4.39
	3000	8103	.0277	.0723	0.479	8.77
	6000	7840	.0263	.0687	0.410	17.5



UNIVERSITY of ALBERTA **DEP'T of CIVIL ENGINEERING** **SOIL MECHANICS LABORATORY** **CONSOLIDATION DATA**	PROJECT AEROSOL 1B SITE Solution Strength - 16.3 % SAMPLE Viscosity = 1.56 ctsk. (Room) LOCATION HOLE DEPTH TECHNICIAN DATE

Ring Data

Ring No. A4

Weight gm's. 467.00

Thickness ins. 0.68

Diameter ins.

Area sq cm's 34.2

Machine Data

Machine No. 4

Multiplication Factor 100

Wt. Block + Stone + Ball gm's.

Consolidation Sample Weights

Wt. Tare + Ring + Soil + Water (End) gms. 602.91

Wt. Tare + Ring + Soil (End) gms. 598.39

Wt. Tare (Tare No T19) gms 38.80

Wt. Ring + Soil + Water (End) gms. 564.11

Wt. Ring + Soil + Water (Start) gms 576.16

Wt. Ring + Soil gms. 550.59

Wt. Soil gms 83.59

Water (End) = 13.52 gms. = 16.20 %

Water (Start) = 25.57 gms = 32.8 %

Description of Sample

Date, Time Load, Dial Remarks	Date, Time Load, Dial Remarks	Date, Time Load, Dial Remarks	Date, Time Load, Dial Remarks	Date, Time Load, Dial Remarks	Date, Time Load, Dial Remarks	Date, Time Load, Dial Remarks
JAN. 26	30 8511	2880 8355	30 8040	FEB. 12	15 7401	2 6904
10:20	60 10	4320 32	1 32	09:09	29 7370	4 6891
20 gm.	140 08	4800 31	2 22	800 gm.	58 36	8 75
0 8595	240 06	5760 8329	4 08	10 7708	135 7286	15 54
6 71	430 03	FEB. 6	9 7790	30 07	250 60	30 25
10 70	1425 8499	09:10	15 78	1 02	470 52	60 6792
15 69	1555 98	200 gm	30 50	2 7618	1420 7247	122 66
30 65	2865 79	6 8301	60 22	4 07	FEB. 17	203 40
1 66	3280 78	10 8295	116 10	29 46	08:53	360 6736
WATER	4320 76	15 90	220 7976	58 31	[illegible] gm.	445 25
2 66	4800 74	30 80	430 49	80 7600	6 7205	1420 6719
4 55	5760 73	1 74	1440 37	115 7586	10 01	
8 55	8600 68	2 68	FEB. 10	217 65	15 7197	
15 46	FEB. 2	4 59	09:05	240 62	30 91	
30 38	09:06	8 45	400 gm.	380 53	1 84	
60 36	100 gm	15 35	6 7798	455 51	2 75	
180 28	6 8452	31 20	10 93	1425 34	4 62	
370 26	10 50	47 09	15 90	1640 34	9 46	
1360 32	15 49	100 8185	30 82	2880 30	15 25	
JAN. 27	30 48	155 72	1 16	5760 7527	30 7098	
09:22	1 44	315 46	2 69	FEB. 16	62 58	
20 gm	2 41	455 40	4 01	09:03	140 12	
6 8522	4 38	1420 22	8 21	1200 gm.	255 6969	
10 21	8 32	2750 17	15 7140	6 7480	455 59	
15 21	15 28	4200 8113	32 34	10 75	1455 6148	
30 20	30 20	FEB. 9	53 14	15 70	FEB. 18	
1 19	52 16	08:50	123 12	30 01	03:16	
2 18	120 01	400 gm.	215 12	1 53	6000 gm.	
4 17	280 8392	6 8063	420 11	2 40	6 6128	
8 16	475 83	10 52	1432 7710	4 31	10 23	
15 13	1430 66	15 47		8 13	15 21	
	1850 65				30 19	
					1 12	

UNIVERSITY of ALBERTA
DEPT. of CIVIL ENGINEERING
SOIL MECHANICS LABORATORY
CONSOLIDATION RESULTS

PROJECT	AEROSOL 1B
SITE	
SAMPLE	
LOCATION	
HOLE	DEPTH
TECHNICIAN	DATE

Specific Gravity of Soil Solids G_s = 2.58 Height of Soil Solids H_s = 0.373 ins.

Void Ratio e (End) = 0.418

Void Ratio e(Start) = 0.921

Void Ratio e (Start Dimensions) = 0.823

$e(End) = W\%(End) \times G_s$ $H_s = \left(\frac{Wt \cdot Soil}{G_s \times Area \times 2.54}\right)$ ins. $e = \text{previous } e \pm \frac{Def'l.}{H_s}$

Time Interval	Load on Pan (gms)	Corr. Dial Reading (ins.)	Deflection (ins.)	$\frac{Deflection}{H_s}$	Void Ratio e	Pressure $Kg/cm^2 = T/ft^2$
	0	8595			0.921	
	20	8532	0.0063	0.0167	0.904	0.070
	50	8468	.0064	.0172	0.887	0.158
	100	8329	.0139	.0372	0.850	0.304
	200	8113	.0216	.0579	0.792	0.596
	400	7710	.0403	.1082	0.683	1.18
	800	7527	.0183	.0490	0.634	2.34
	1500	7247	.0280	.0750	0.559	4.51
	3000	6948	.0299	.0800	0.479	8.77
	6000	6719	.0229	.0614	0.418	17.5

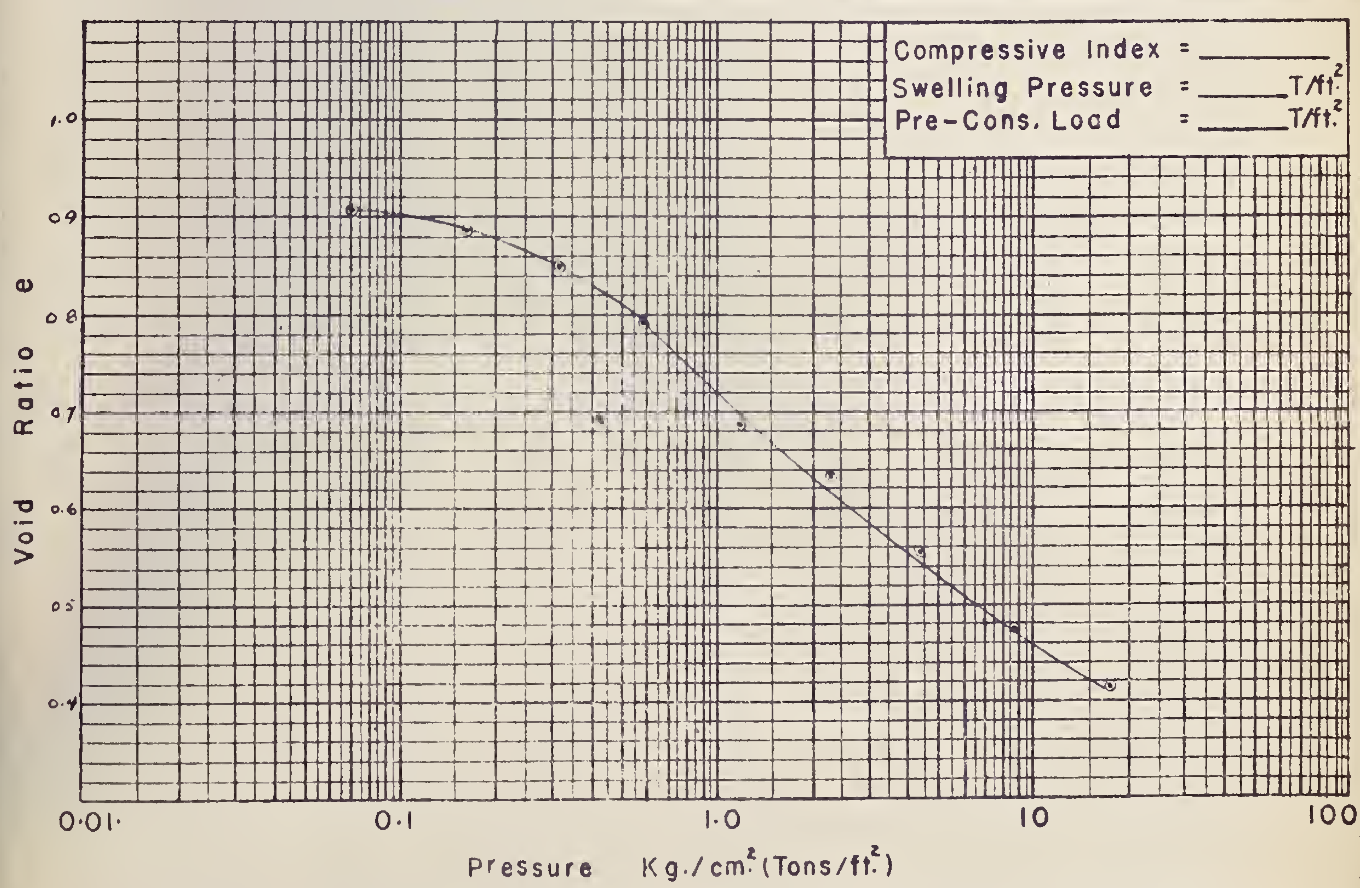


TABLE XXXIII.

UNIVERSITY of ALBERTA
DEP'T of CIVIL ENGINEERING
SOIL MECHANICS LABORATORY

CONSOLIDATION DATA

PROJECT AEROSOL MA
SITE Solution Strength = 15.9%
SAMPLE Viscosity = 2.60 ctk. (Room)
LOCATION
HOLE DEPTH
TECHNICIAN DATE

Ring Data

Ring No. A5
Weight gm's. 465.82
Thickness ins. 0.68
Diameter ins.
Area sq cm's 34.2

Machine Data

Machine No. 3
Multiplication Factor 100
Wt Block + Stone + Ball gm's.

Consolidation Sample Weights

Wt. Tare + Ring + Soil + Water (End) gms. 591.03
Wt. Tare + Ring + Soil (End) gms. 577.68
Wt. Tare (Tare No T5) gms. 29.60
Wt. Ring + Soil + Water (End) gms. 561.43
Wt Ring + Soil + Water (Start) gms 573.92
Wt Ring + Soil gms. 548.08
Wt. Soil gms 82.26
Water (End) = 13.35 gms. = 16.2 %
Water (Start) = 25.84 gms = 31.4 %

Description of Sample

Date, Time Load, Dial Remarks	Date, Time Load, Dial Remarks	Date, Time Load, Dial Remarks	Date, Time Load, Dial Remarks	Date, Time Load, Dial Remarks	Date, Time Load, Dial Remarks	Date, Time Load, Dial Remarks
JAN. 20	142 7413	JAN. 28	15 6710	310 6456	8 6050	
16:27	210 10	07:14	30 02	440 47	23 14	
20 gm	440 7397	200 gm	1 6897	1440 6431	31 01	
0 7524	1430 89	6 7192	2 88	FEB. 5	40 5987	
6 7470	1910 83	10 85	4 83	09:08	92 37	
10 68	2870 81	15 82	8 74	1500 gm.	[illegible] 17	
15 67	3360 79	30 76	15 67	6 6383	305 5893	
30 66	5900 73	1 67	30 58	10 76	450 81	
1 65	7200 73	2 61	64 47	15 72	1420 70	
WATER	JAN. 26	4 51	150 33	30 68	4320 69	
2 7468	09:15	8 42	273 18	1 58	FEB. 9	
4 67	100 gm	15 28	480 6800	2 47	08:46	
8 69	6 7351	30 09	1440 6778	4 36	6000 gm	
15 71	10 48	60 7084	1860 78	8 20	6 5850	
1000 67	15 47	120 56	2830 78	15 6300	10 48	
JAN. 21	30 45	207 32	FEB. 4	35 6265	15 45	
09:12	1 43	235 19	07:06	69 28	30 41	
50 gm	2 37	440 04	800 gms.	122 6199	1 36	
6 7445	4 37	1430 6988	6 6705	250 67	2 30	
10 43	8 29	1760 62	10 02	435 55	4 18	
15 42	21 19	2880 72	15 6696	1440 6144	8 08	
30 41	31 13	3360 72	30 86	FEB 6	15 5792	
1 40	60 01	4320 69	1 74	07:17	30 65	
2 39	120 7286	7200 62	2 62	3000 gm	60 31	
4 38	240 71	FEB. 2	4 45	6 6110	120 05	
8 34	420 59	09:04	8 31	10 03	220 5665	
15 31	1425 38	400 gm.	15 19	15 01	435 51	
30 25	1880 35	6 6725	30 6576	30 6099	1440 38	
60 21	2880 35	10 18	84 20	1 90	1770 5637	
			144 01	2 80		
				4 68		

TABLE XXXIII(a).

UNIVERSITY of ALBERTA
DEPT. of CIVIL ENGINEERING
SOIL MECHANICS LABORATORY
CONSOLIDATION RESULTS

PROJECT	AEROSOL MA
SITE	
SAMPLE	
LOCATION	
HOLE	DEPTH
TECHNICIAN	DATE

Specific Gravity of Soil Solids G_s = 2.58 Height of Soil Solids H_s = 0.367 ins.

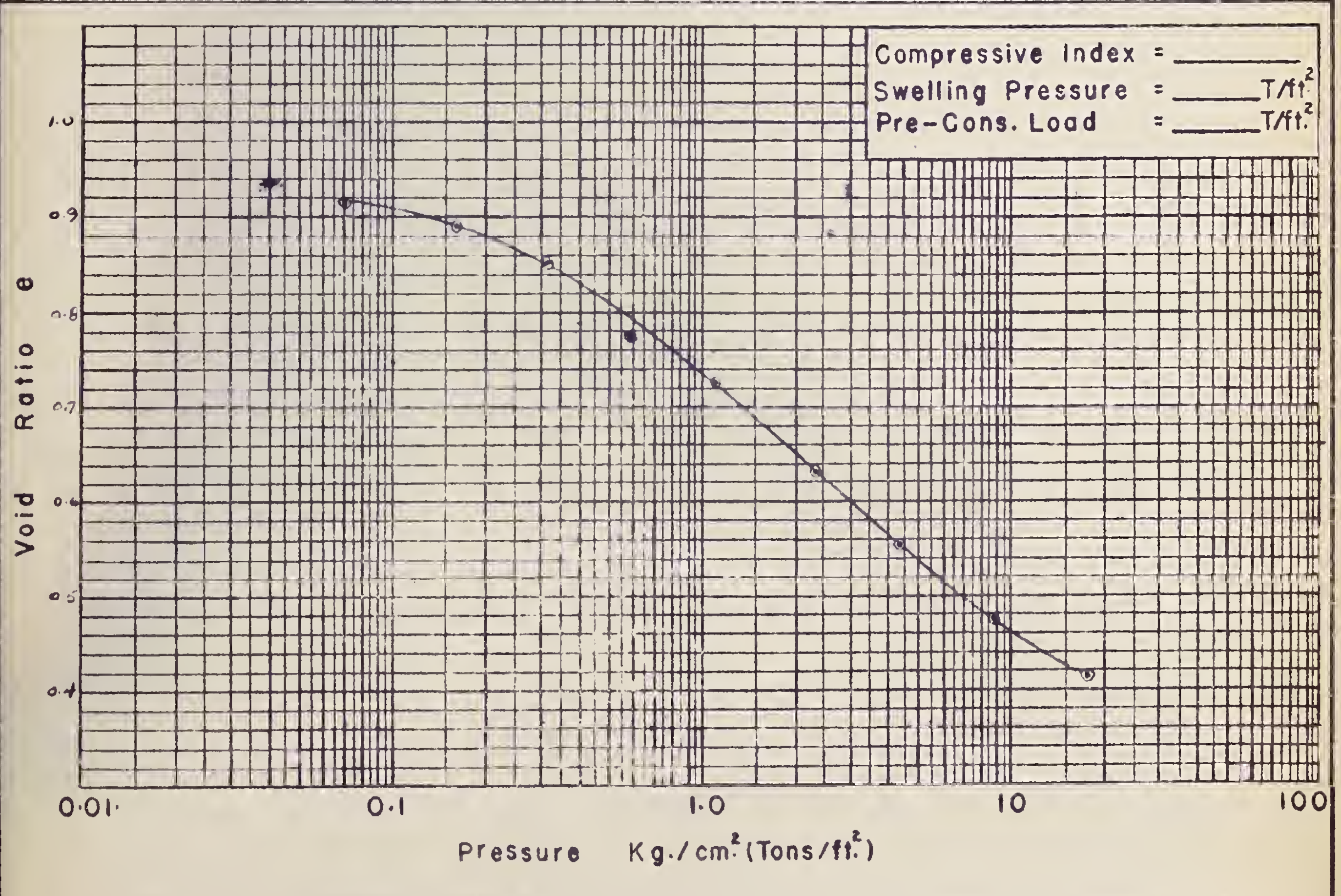
Void Ratio e (End) = 0.416

Void Ratio e(Start) = 0.931

Void Ratio e (Start Dimensions) = 0.854

$e(End) = W\%(End) \times G_s$ $H_s = \left(\frac{Wt \cdot Soil}{G_s \times Area \times 2.54}\right)$ ins. $e = \text{previous } e \pm \frac{Def'l.}{H_s}$

Time Interval	Load on Pan (gms)	Corr. Dial Reading (ins.)	Deflection (ins.)	Deflection / H_s	Void Ratio e	Pressure $Kg/cm^2 = T/ft^2$
	0	7524			0.931	
	20	7469	0.0055	0.0150	0.916	0.070
	50	7373	.0096	.0262	0.890	0.158
	100	7235	.0138	.0377	0.852	0.304
	200	6962	.0273	.0746	0.777	0.594
	400	6778	.0184	.0504	0.727	1.18
	800	6431	.0347	.0946	0.682	2.34
	1600	6144	.0287	.0784	0.554	4.39
	3000	5869	.0275	.0752	0.479	8.77
	6000	5637	.0232	.0632	0.416	17.5



UNIVERSITY of ALBERTA
DEP'T of CIVIL ENGINEERING
SOIL MECHANICS LABORATORY

CONSOLIDATION DATA

PROJECT	AEROSOL O.S.
SITE	Solution Strength = 15.3%
SAMPLE	Viscosity = 1.42 cstks (Room)
LOCATION	
HOLE	DEPTH
TECHNICIAN	DATE

Ring Data

Ring No. A-4
Weight gms. 46700
Thickness ins. 0.68
Diameter ins. 39.07 cm³
Area sq. cm's 34.2

Machine Data

Machine No. 2
Multiplication Factor 1:100
Wt Block + Stone + Ball gms.

Consolidation Sample Weights

Wt. Tare + Ring + Soil + Water (End) gms 399.26
Wt. Tare + Ring + Soil (End) gms. 386.00
Wt. Tare (Tare No T11) gms 36.68
Wt. Ring + Soil + Water (End) gms 362.58
Wt. Ring + Soil + Water (Start) gms 376.18
Wt. Ring + Soil gms 349.32
Wt. Soil gms 82.32
Water (End) = 13.26 gms. = 16.1 %
Water (Start) = 26.86 gms = 32.7 %

Description of Sample Initial Wet Density = 115.4 #/ft.³
Initial Dry Density = 86.9 #/ft.³

Date, Time Load, Dial Remarks	Date, Time Load, Dial Remarks	Date, Time Load, Dial Remarks	Date, Time Load, Dial Remarks	Date, Time Load, Dial Remarks	Date, Time Load, Dial Remarks	Date, Time Load, Dial Remarks
JAN. 5	30 9338	4300 9144	4 8762	2860 8233	73 7814	
1117	60 32	JAN. 14	9 48	JAN. 21	132 7779	
20 gm.	120 27	09:38	15 35	09:16	210 58	
0 9470	240 18	200 gm.	30 13	1500 gm.	450 41	
6 18	440 12	6 9100	60 8689	6 8226	1430 26	
15 1[illegible]	1425 9300	10 9099	110 54	10 22	JAN. 23	
30 13	1850 9298	15 95	220 17	15 18	09:11	
1 09	2880 88	30 90	440 8587	30 06	6000 gm.	
2 07	4380 87	1 85	1600 58	1 8198	3 7702	
WATER	5760 85	2 78	2850 52	2 92	6 01	
4 9407	8640 82	4 69	JAN. 19	4 84	10 7699	
8 02	JAN. 12	8 55	09:06	8 73	15 95	
15 9400	09:21	15 43	800 gm.	15 57	30 91	
20 9398	100 gm.	30 26	6 8498	30 34	1 86	
120 97	6 9268	60 06	10 93	60 02	2 77	
230 91	10 66	120 8972	15 90	140 8033	4 66	
1330 91	15 65	240 39	30 80	208 35	8 51	
JAN 6	30 62	390 15	1 72	450 15	15 34	
09:02	1 58	1415 8868	2 66	1440 7978	30 15	
50 gm.	2 56	1835 58	4 53	JAN. 22	60 7573	
6 9372	4 50	2850 43	6 47	09:18	129 36	
10 70	8 47	4300 43	9 44	3000 gm.	194 20	
15 69	15 40	JAN. 17	15 23	6 79[illegible]8	295 01	
30 68	30 30	09:26	30 01	10 55	480 7438	
1 57	60 21	400 gm.	60 8368	15 52	3000 7477	
2 53	120 07	6 8798	120 27	30 47		
4 48	250 9189	10 95	245 8287	1 40		
6 46	460 75	16 92	470 60	2 32		
11 42	1425 43	20 87	1440 39	4 20		
18 41		1 81	1860 36	8 03		
		2 72		15 7888		
				30 62		

UNIVERSITY of ALBERTA
DEPT. of CIVIL ENGINEERING
SOIL MECHANICS LABORATORY
CONSOLIDATION RESULTS

PROJECT	AEROSOL 03
SITE	
SAMPLE	
LOCATION	
HOLE	DEPTH
TECHNICIAN	DATE

Specific Gravity of Soil Solids G_s = 2.58 Height of Soil Solids H_s = 0.367 ins.

Void Ratio e (End) = 0.416

Void Ratio e(Start) = 0.961

Void Ratio e (Start Dimensions) = 0.852

e(End) = W%(End) x G_s $\qquad H_s = \left(\frac{\text{Wt. Soil}}{G_s \times \text{Area} \times 2.54}\right)$ ins. $\qquad e$ = previous $e \pm \frac{\text{Def'l.}}{H_s}$

Time Interval	Load on Pan (gms)	Corr. Dial Reading (ins.)	Deflection (ins.)	Deflection / H_s	Void Ratio e	Pressure $Kg/cm^2 = T/ft^2$
	0	9470			0.961	
	20	9391	0.0079	0.0216	0.939	0.070
	50	9282	.0109	.0298	0.910	0.138
	100	9144	.0138	.0377	0.872	0.304
	200	8843	.0301	.0823	0.790	0.596
	400	8552	.0291	.0796	0.710	1.18
	800	8233	.0319	.0872	0.623	2.34
	1300	7998	.0235	.0643	0.539	4.32
	3000	7726	.0272	.0744	0.484	8.77
	6000	7477	.0249	.0681	0.416	17.2

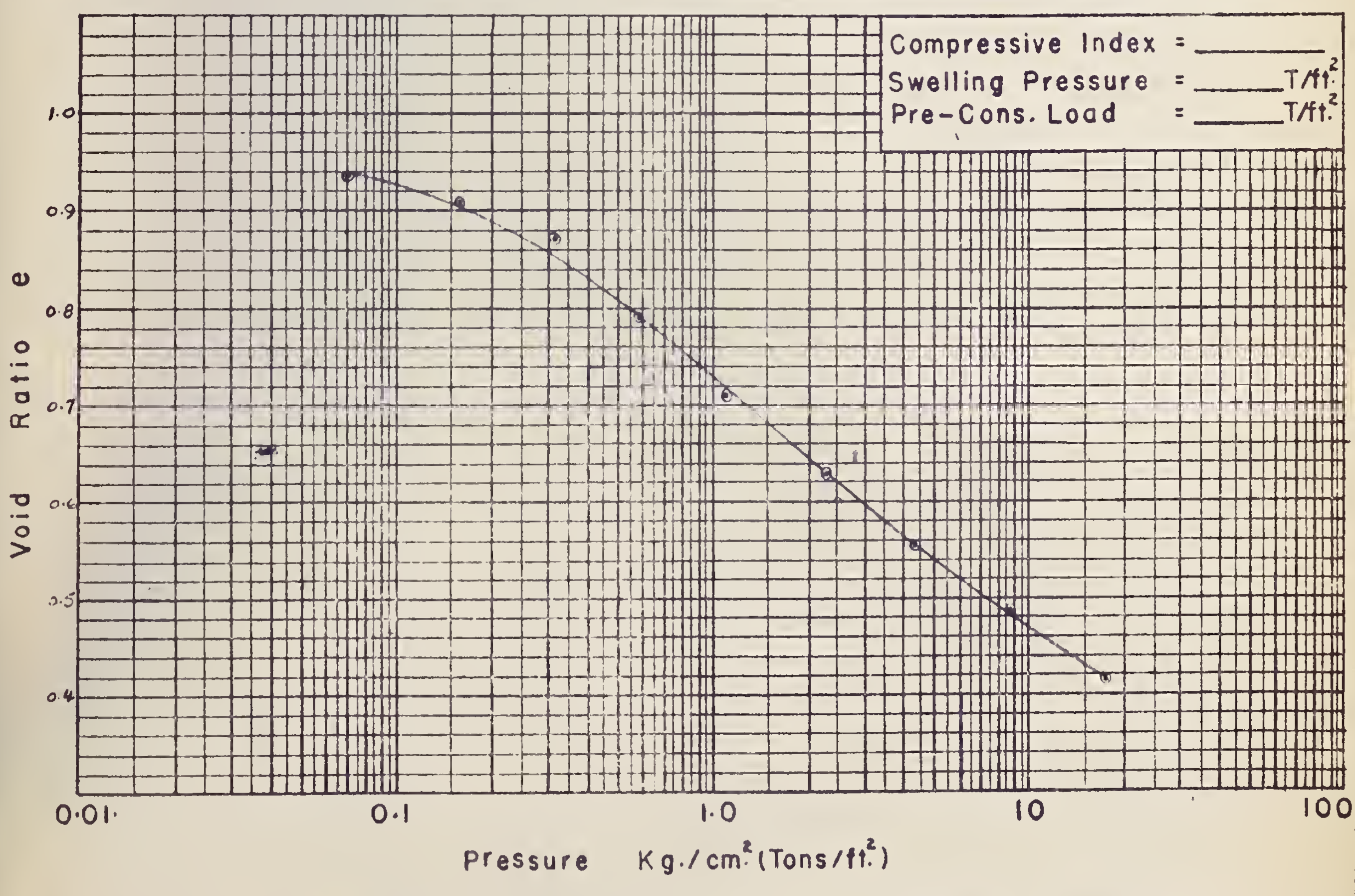


TABLE XXXV.

UNIVERSITY of ALBERTA DEP'T of CIVIL ENGINEERING SOIL MECHANICS LABORATORY **CONSOLIDATION DATA**	PROJECT LIGNOSOL BD SITE Solution Strength = 16% SAMPLE Viscosity = 1.7c th. (Room) LOCATION HOLE DEPTH TECHNICIAN DATE

Ring Data

- Ring No. A-1
- Weight gm's. 469.85
- Thickness ins 0.68
- Diameter ins.
- Area sq. cm's 34.2

Machine Data

- Machine No. 3
- Multiplication Factor 100
- Wt. Block + Stone + Ball gm's.

Consolidation Sample Weights

- Wt. Tare + Ring + Soil + Water (End) gms 610.61
- Wt. Tare + Ring + Soil (End) gms. 596.98
- Wt. Tare (Tare No ______) gms 41.78
- Wt. Ring + Soil + Water (End) gms 568.83
- Wt. Ring + Soil + Water (Start) gms 581.92
- Wt. Ring + Soil gms 555.20
- Wt. Soil gms 85.35
- Water (End) = 13.63 gms. = 16.0 %
- Water (Start) = 26.72 gms = 31.3 %

Description of Sample

Date, Time Load, Dial Remarks	Date, Time Load, Dial Remarks	Date, Time Load, Dial Remarks	Date, Time Load, Dial Remarks	Date, Time Load, Dial Remarks	Date, Time Load, Dial Remarks	Date, Time Load, Dial Remarks
JAN. 2	50 6884	JAN. 3	1 6436	1452 5950	4 5624	
14:30	110 73	10:06	2 29	JAN. 15	8 10	
20gm.	1620 32	200gm.	4 24	14:29	15 5593	
0 6952	2850 27	6 6661	8 13	1500gm.	30 67	
6 30	3250 25	10 59	15 02	6 5925	60 37	
10 28	4280 21	15 58	30 6385	10 20	120 02	
15 27	JAN. 6	30 55	66 58	20 14	220 5470	
30 26	08:56	1 52	122 27	30 09	440 52	
1 25	100gm.	2 48	250 6287	1 5900	1600 32	
2 25	6 6811	4 43	440 68	2 5895	2850 26	
WATER	10 10	8 37	1455 43	4 84	JAN. 19	
4 6935	15 09	15 28	1680 38	8 71	09:00	
8 38	30 06	30 12	JAN. 14	15 52	6000gm.	
15 38	1 07	60 6589	14:14	30 31	6 5404	
30 38	2 05	105 68	800gm	60 5800	10 02	
75 38	4 03	180 48	6 6198	100 5774	15 5400	
120 38	11 6798	310 28	10 95	127 59	30 5396	
1150 38	17 13	420 23	15 92	1120 5699	1 90	
JAN. 13	30 88	1380 6497	30 88	1425 97	2 83	
09:36	60 77	1540 94	1 73	2550 92	4 73	
50gm	125 62	4260 78	2 68	JAN. 17	8 64	
6 6906	250 48	5700 75	4 52	09:20	15 47	
10 04	450 32	JAN. 13	8 41	3000gm.	30 24	
15 03	1430 11	09:15	15 26	6 5655	63 5292	
30 02	1850 09	400gm	30 01	10 53	120 59	
1 02	2890 6692	6 6447	60 6068	15 52	255 31	
2 01	4380 81	10 45	120 32	30 48	470 15	
4 6893		15 42	1140 5958	1 42	1440 5189	
8 98		30 38		2 34	1860 5169	
20 92						

UNIVERSITY of ALBERTA
DEPT. of CIVIL ENGINEERING
SOIL MECHANICS LABORATORY

CONSOLIDATION RESULTS

PROJECT	LIGNOSOL BD
SITE	
SAMPLE	
LOCATION	
HOLE	DEPTH
TECHNICIAN	DATE

Specific Gravity of Soil Solids G_s = 2.58 Height of Soil Solids H_s = 0.381 ins.

Void Ratio e (End) = 0.413

Void Ratio e(Start) = 0.877

Void Ratio e (Start Dimensions) = 0.785

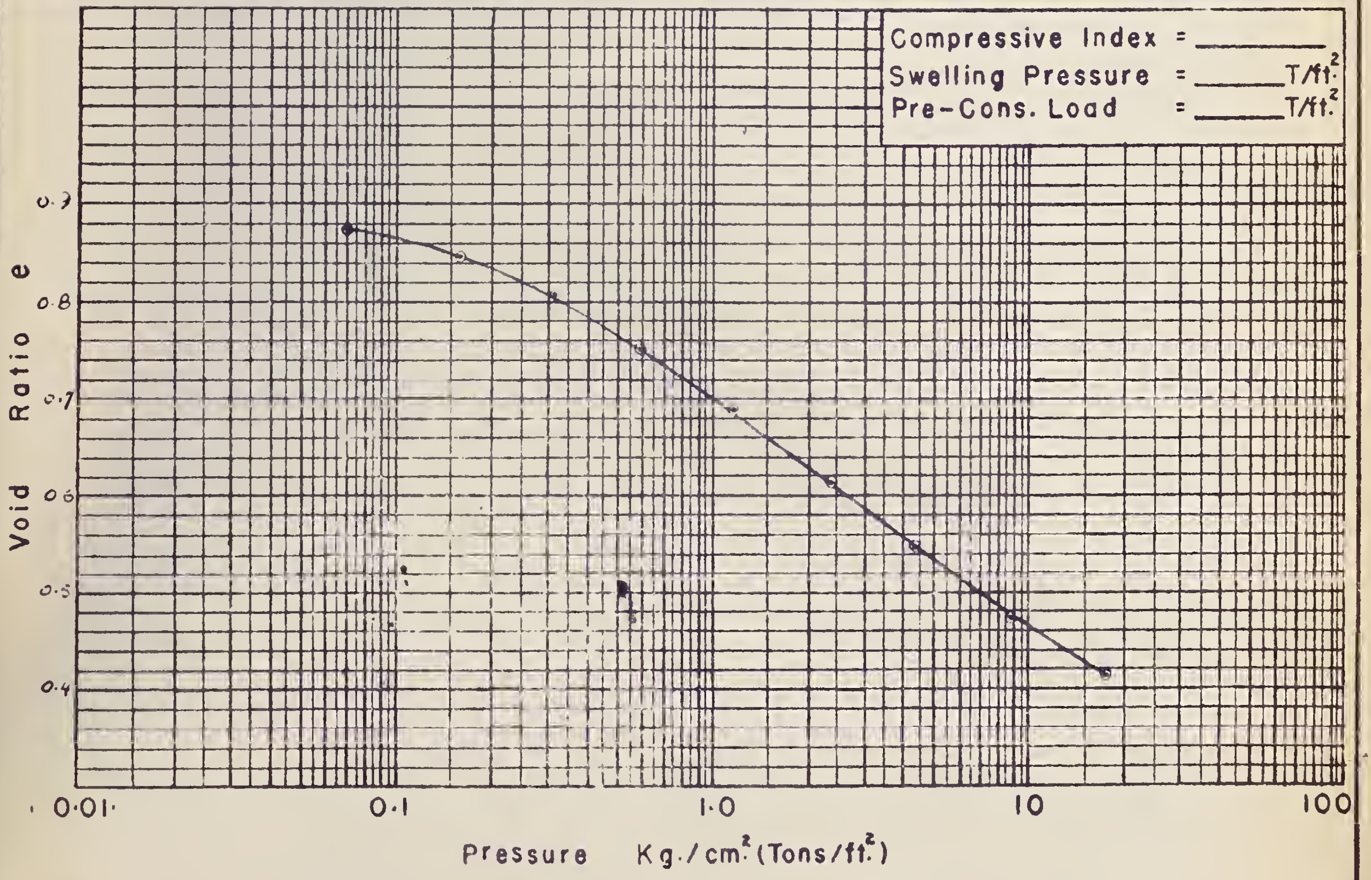
$e(End) = W\%(End) \times G_s$ $\quad H_s = \left(\frac{Wt.\ Soil}{G_s \times Area \times 2.54}\right)$ ins. $\quad e$ = previous $e \pm \frac{Def'l.}{H_s}$

Time Interval	Load on Pan (gms)	Corr. Dial Reading (ins.)	Deflection (ins.)	$\frac{\text{Deflection}}{H_s}$	Void Ratio e	Pressure $Kg/cm^2 = T/ft^2$
	0	6952			0.877	
	20	6938	0.0014	0.0037	0.874	0.070
	50	6821	0.0117	0.0308	0.843	0.158
	100	6681	.0140	.0369	0.806	0.304
	200	6475	.0206	.0542	0.752	0.536
	400	6238	.0237	.0624	0.689	1.18
	800	5950	.0288	.0759	0.614	2.34
	1500	5692	.0258	.0680	0.546	4.32
	3000	5426	.0266	.0700	0.476	8.77
	6000	5189	.0237	.0625	0.413	17.5

Compressive Index = ______

Swelling Pressure = ______ T/ft^2

Pre-Cons. Load = ______ T/ft^2



UNIVERSITY of ALBERTA
DEP'T of CIVIL ENGINEERING
SOIL MECHANICS LABORATORY
CONSOLIDATION DATA

PROJECT WANO OL XD
SITE Solution Strength: 18.1%
SAMPLE Viscosity = 2.18 c.tk. (Room)
LOCATION
HOLE DEPTH
TECHNICIAN DATE

Ring Data
Ring No. A-3
Weight gm's. 463.55
Thickness ins. 0.68
Diameter ins.
Area sq cm's 34.2

Machine Data
Machine No. 4
Multiplication Factor 100
Wt Block + Stone + Ball gm's.

Consolidation Sample Weights
Wt. Tare + Ring + Soil + Water (End) gms 607.62
Wt. Tare + Ring + Soil (End) gms. 588.97
Wt. Tare (Tare No T1) gms 33.93
Wt. Ring + Soil + Water (End) gms. 573.69
Wt Ring + Soil + Water (Start) gms 580.25
Wt Ring + Soil gms 555.04
Wt. Soil gms. 91.49
Water (End) = 18.65 gms. = 20.4 %
Water (Start) = 25.21 gms = 27.5 %

Description of Sample Initial Wet Density = 125.4 #/ft.^{3}
Initial Dry Density = 98.3 #/ft.^{3}

Date, Time Load, Dial Remarks	Date, Time Load, Dial Remarks	Date, Time Load, Dial Remarks	Date, Time Load, Dial Remarks	Date, Time Load, Dial Remarks	Date, Time Load, Dial Remarks	Date, Time Load, Dial Remarks
JAN. 5	15 8444	5460 8287	30 8071	1660 7702	8 7553	
11:23	30 41	6900 72	1 67	2880 7700	15 52	
20 gm	60 38	9780 69	2 61	JAN 21	30 52	
0 8523	120 33	JAN. 14	4 55	09:14	76 50	
6 8452	240 31	09:35	8 47	1500 gm.	135 48	
10 51	445 28	200 gm.	16 34	6 7672	210 49	
15 49	1425 22	6 8255	30 22	10 70	465 49	
30 47	1850 20	10 53	60 02	15 68	1430 49	
1 45	2890 8394	15 52	115 7979	30 64	JAN. 23	
2 42	3190 92	30 50	220 53	1 60	09:08	
WATER	JAN 8	1 48	440 34	2 55	6000 gm	
4 45	14:29	2 44	1600 08	4 50	6 7549	
8 48	100 gm.	4 40	2850 7902	8 42	10 48	
15 45	6 8382	8 36	JAN. 19	15 34	15 48	
110 47	10 81	15 31	09:03	30 20	30 48	
270 52	15 80	30 22	800 gm.	60 02	1 48	
1330 8462	30 77	60 11	6 7853	140 7592	2 46	
JAN 6	1 73	120 8196	10 50	210 72	4 48	
08:59	2 70	240 79	15 46	440 72	8 48	
50 gm.	4 68	400 65	30 40	1430 68	15 48	
6 8456	8 64	1420 42	1 33	JAN. 22	30 48	
10 55	15 60	1730 15	2 26	09:12	57 48	
15 54	26 57	2850 05	4 18	3000 gm	130 45	
30 53	60 45	4800 64	8 06	6 7565	207 46	
1 52	105 33	JAN 17	16 7794	10 63	300 45	
2 51	1170 02	09:23	30 81	15 60	475 45	
4 40	1500 8298	400 gm,	62 61	30 58	3000 7545	
8 48	2550 93	6 8080	120 42	1 51		
		10 75	250 27	2 36		
		15 76	470 13	4 35		
			1440 02			

UNIVERSITY of ALBERTA DEPT. of CIVIL ENGINEERING SOIL MECHANICS LABORATORY CONSOLIDATION RESULTS	
	PROJECT LIGNOSOL XD
	SITE
	SAMPLE
	LOCATION
	HOLE DEPTH
	TECHNICIAN DATE

Specific Gravity of Soil Solids G_s = 2.58 Height of Soil Solids H_s = 0.407 ins.

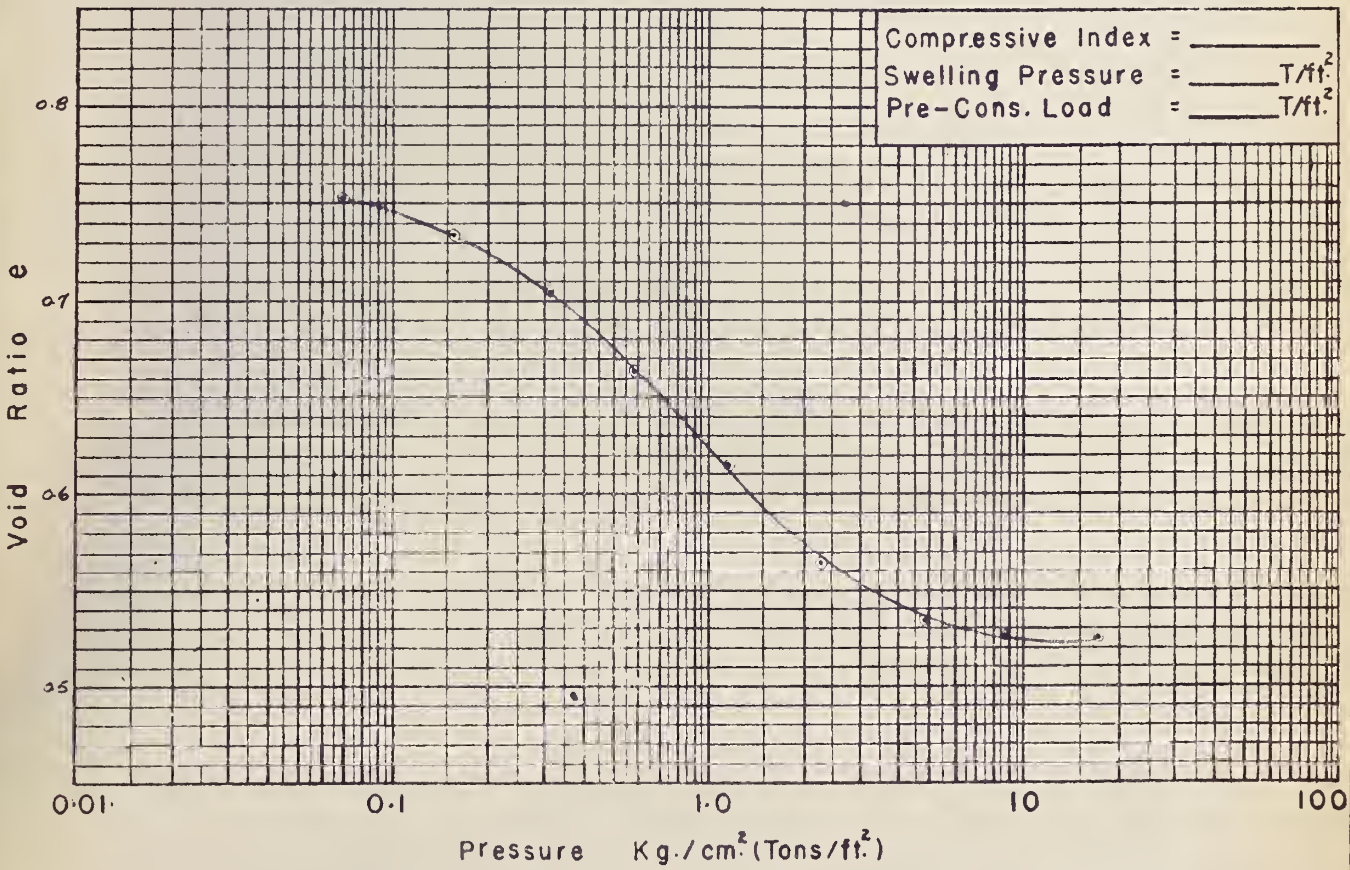
Void Ratio e (End) = 0.526

Void Ratio e(Start) = 0.768

Void Ratio e (Start Dimensions) = 0.671

$e(End) = W\%(End) \times G_s$ $\qquad H_s = \left(\frac{Wt \cdot Soil}{G_s \times Area \times 2.54}\right) ins.$ $\qquad e = \text{previous } e \pm \frac{Def'l.}{H_s}$

Time Interval	Load on Pan (gms)	Corr. Dial Reading (ins.)	Deflection (ins.)	Deflection / H_s	Void Ratio e	Pressure $Kg/cm^2 = T/ft^2$
	0	.8529			0.768	
	20	.8462	0.0067	0.0165	0.751	.070
	50	.8392	0.0070	.0172	0.734	0.158
	100	.8269	.0123	.0302	0.704	0.304
	200	.8104	.0165	.0410	0.663	0.596
	400	.7902	.0202	.0496	0.614	1.18
	800	.7700	.0202	.0496	0.564	2.34
	1500	.7568	.0132	.0324	0.532	4.39
	3000	.7549	.0019	.0047	0.527	8.77
	6000	.7545	.0004	.0010	0.526	17.5



UNIVERSITY of ALBERTA
DEP'T of CIVIL ENGINEERING
SOIL MECHANICS LABORATORY

CONSOLIDATION DATA

PROJECT LIGNOSOL BD
SITE Sol'n. Strength = 14.5 %
SAMPLE Viscosity = 1.60 ctsk. (Room)
LOCATION
HOLE DEPTH
TECHNICIAN DATE

Ring Data
Ring No. B-13
Weight gm's. 613.09
Thickness ins.
Diameter ins.
Area sq cm's 34.2

Machine Data
Machine No. 4
Multiplication Factor 100
Wt Block + Stone + Ball gm's. 92

Consolidation Sample Weights
Wt. Tare + Ring + Soil + Water (End) gms 773.58
Wt. Tare + Ring + Soil (End) gms. 756.42
Wt. Tare (Tare No 115) gms 34.66
Wt Ring + Soil + Water (End) gms 738.92
Wt Ring + Soil + Water (Start) gms 758.95
Wt Ring + Soil gms 721.76
Wt. Soil gms 108.67
Water (End) = 17.16 gms. = 15.[illegible] %
Water (Start) = 37.19 gms = 34.4 %

Description of Sample Initial Wet Density = 116.2 #/ft³
Initial Dry Density = 86.4 #/ft³

Date, Time Load, Dial Remarks	Date, Time Load, Dial Remarks	Date, Time Load, Dial Remarks	Date, Time Load, Dial Remarks	Date, Time Load, Dial Remarks	Date, Time Load, Dial Remarks	Date, Time Load, Dial Remarks
DEC. 8	4 7496	78 7279	1610 6883	DEC. 24	8 5986	JAN. 2
10:47	8 93	125 60	3000 72	08:57	15 72	09:28
20 gm	15 83	240 46	4300 6865	800 gms.	30 55	6000 gm
0 7660	30 78	380 24	DEC. 22	3 6458	60 18	6 5420
6 7518	45 74	435 21	08:41	6 51	130 5880	10 18
10 77	160 47	1440 08	400 gms.	10 45	270 40	15 16
15 75	60 26	1240 7203	3 6838	15 39	360 27	30 13
30 73	1380 9393	288 7200	6 33	30 30	460 18	1 08
1 72	2760 62	DEC. 19	10 28	1 20	1475 5789	2 5400
2 68	4100 55	09:03	15 22	2 05	1825 84	4 5389
WATER	5600 42	200 gm.	30 12	4 6389	2330 78	8 70
4 7571	8300 27	3 7178	1 03	8 68	DEC 31	15 58
8 70	9960 25	6 74	2 6792	15 47	07:42	30 27
15 70	11,400 24	10 71	4 80	30 28	3000 gm	60 5290
30 66	DEC. 17	15 69	8 61	60 6272	6 5748	120 42
60 63	08:58	30 65	20 40	120 12	10 44	230 5200
230 43	100 gm	1 59	30 28	360 6139	15 39	340 5188
[illegible] 40	3 7509	2 52	60 6665	1760 6098	30 34	420 31
1440 23	6 05	4 38	120 23	4320 86	1 27	1440 38
DEC 9	10 07	8 28	175 6598	7200 81	2 10	3060 49
11:01	15 06	15 12	230 74	DEC 29	4 02	4300 48
50 gm.	30 05	30 7088	330 58	08:4[illegible]	8 5687	
6 7510	1 04	60 56	460 43	1500 gm.	15 58	
10 08	2 02	120 15	1450 13	6 6048	30 31	
15 07	4 7291	210 6973	1670 11	10 44	60 5583	
20 06	8 97	300 42	2800 6500	15 40	120 32	
1 03	15 92	420 23		30 32	225 5411	
2 7500	30 84	1430 6807		1 25	270 65	
3 7497				2 15	1830 41	
				4 02	2550 5438	

TABLE XXXVII(a)

UNIVERSITY of ALBERTA
DEPT· of CIVIL ENGINEERING
SOIL MECHANICS LABORATORY

CONSOLIDATION RESULTS

PROJECT	LIGNOSOL BD
SITE	
SAMPLE	
LOCATION	
HOLE	DEPTH
TECHNICIAN	DATE

Specific Gravity of Soil Solids G_s = 2.58 Height of Soil Solids H_s = 0.484 ins.

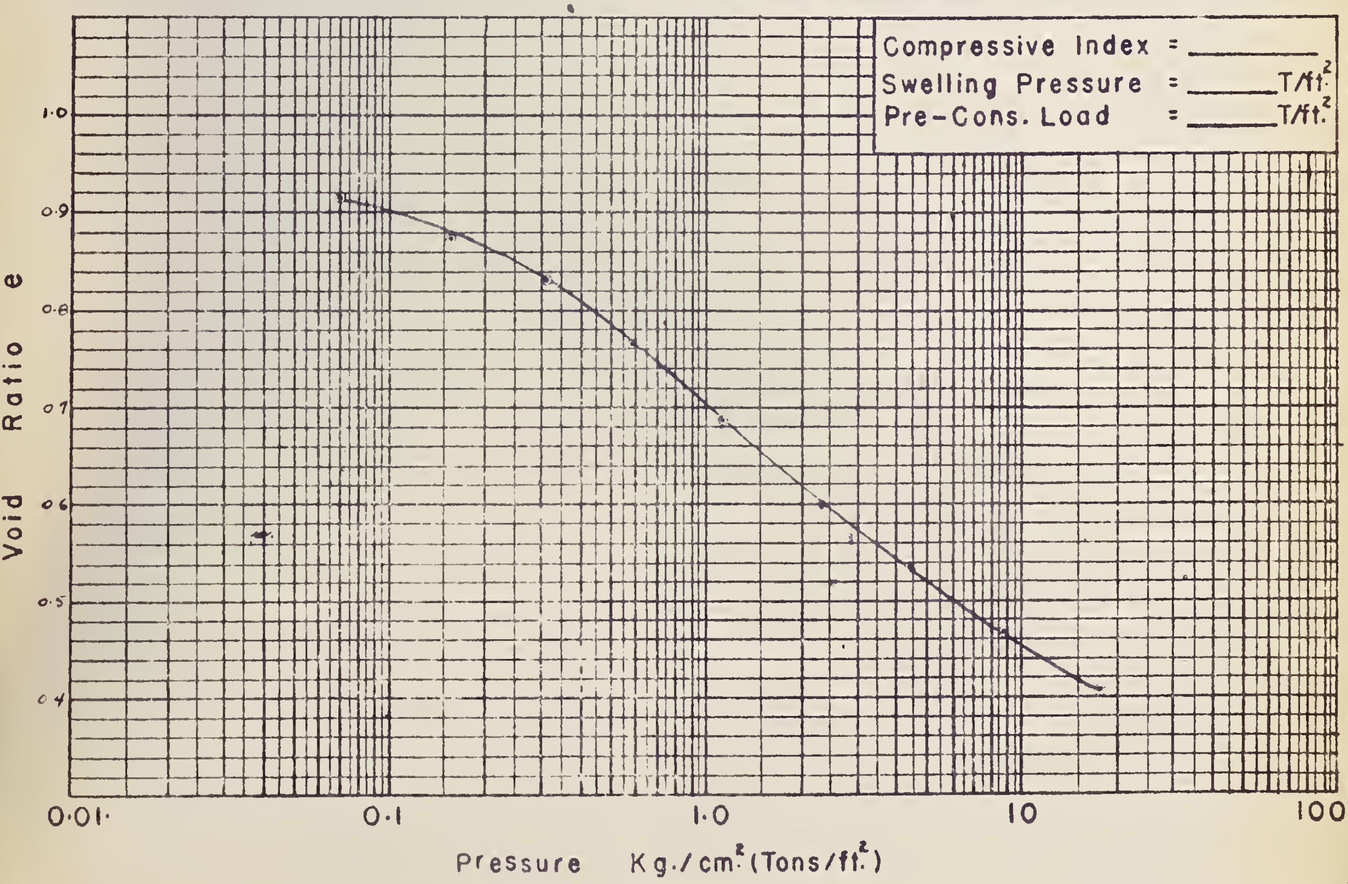
Void Ratio e (End) = 0.407

Void Ratio e(Start) =

Void Ratio e (Start Dimensions) =

e(End) = W%(End) x G_s $H_s = \left(\frac{\text{Wt}\cdot\text{Soil}}{G_s \times \text{Area} \times 2\cdot 54}\right)$ ins. $e' = \text{previous } e \pm \frac{\text{Def'l.}}{H_s}$

Time Interval	Load on Pan (gms)	Corr. Dial Reading (ins.)	Deflection (ins.)	Deflection / H_s	Void Ratio e	Pressure $Kg/cm^2 = T/ft^2$
	0	7660			0.946	
	20	7523	0.0137	0.0283	0.918	0.070
	50	7324	0.0199	.0411	0.876	0.138
	100	7200	·0124	·0426	0.831	0.304
	200	6865	·0335	·0692	0.762	0.596
	400	6500	·0365	·0754	0.686	1.18
	800	6081	·0419	·0866	0.600	2.34
	1500	5778	·0303	·0626	0.537	4.39
	3000	5438	·0340	·0703	0.467	8.77
	6000	5148	·0290	·0599	0.407	17.5



UNIVERSITY of ALBERTA DEP'T of CIVIL ENGINEERING SOIL MECHANICS LABORATORY **CONSOLIDATION DATA**	
PROJECT	Sugar Beet
SITE	Molasses
SAMPLE	Solution Strength = 15.8 %
LOCATION	Viscosity = 1.87 ctsk. (Room)
HOLE	DEPTH
TECHNICIAN	DATE

Ring Data

- Ring No. B-6
- Weight gm's. 596.58
- Thickness ins. 0.9
- Diameter ins. -
- Area sq cm's 34.2

Machine Data

- Machine No. 3
- Multiplication Factor 100
- Wt. Block + Stone + Ball gm's. 377

Consolidation Sample Weights

- Wt. Tare + Ring + Soil + Water (End) gms 762.35
- Wt. Tare + Ring + Soil (End) gms. 743.38
- Wt. Tare (Tare No T15) gms 34.66
- Wt. Ring + Soil + Water (End) gms 727.69
- Wt. Ring + Soil + Water (Start) gms 744.25
- Wt. Ring + Soil gms 708.72
- Wt. Soil gms 112.14
- Water (End) = 18.97 gms. = 16.9 %
- Water (Start) = 35.53 gms = 31.7 %

Description of Sample Initial Wet Density = 118.0 #/ft³
Initial Dry Density = 89.7 #/ft³

Date, Time Load, Dial Remarks	Date, Time Load, Dial Remarks	Date, Time Load, Dial Remarks	Date, Time Load, Dial Remarks	Date, Time Load, Dial Remarks	Date, Time Load, Dial Remarks	Date, Time Load, Dial Remarks
Dec. 8	4 7198	4350 6935	4 6428	180 5900	15 5323	225 4774
10:40	8 98	Dec. 15	8 19	260 5872	30 21	370 30
20 gm	15 97	10:51	15 04	330 47	1 18	1850 4665
0 6978	30 7215	200 gm.	30 6389	465 20	2 13	2880 4662
2 72	48 18	6 6834	60 72	1450 5740	4 05	
6 71	160 20	10 32	90 57	1870 35	8 5296	
10 71	360 12	15 26	165 28	2880 5721	15 83	
15 71	1380 7177	30 22	300 6298	Dec. 24	30 57	
30 70	2760 58	1 15	400 82	08:54	60 30	
1 60	4300 7152	2 11	1440 03	1500 gm	120 5199	
2 69	Dec. 12	4 6802	1770 6192	6 5681	270 16	
WATER	08:35	7 6792	2880 76	10 78	360 5090	
4 72	100 gm	15 77	4350 66	15 75	460 67	
8 69	3 7111	40 44	7250 6160	30 68	1480 5003	
15 69	6 10	130 6682	Dec. 22	1 63	1930 4997	
30 73	10 01	200 42	08:38	2 57	2980 4990	
60 7000	15 08	360 18	800 gm	4 48	Dec. 31	
255 43	30 07	1320 6575	3 6088	8 36	09:39	
330 7228	1 04	1710 54	6 81	15 22	6000 gm	
1450 7272	2 02	2820 45	10 75	30 01	6 4975	
Dec. 9	4 7095	3250 39	15 70	60 5578	10 73	
10:57	8 93	4200 6538	30 60	120 59	15 72	
50 gm.	15 92	Dec. 18	1 52	360 5452	30 71	
3 7223	30 90	08:54	2 41	1360 5365	1 68	
6 22	60 87	400 gm	4 31	4320 5348	2 63	
10 18	100 85	3 6475	8 20	7200 5342	4 56	
15 12	170 85	6 68	15 07	Dec. 29	8 44	
30 08	275 85	10 62	30 5986	08:42	20 22	
1 03	460 6964	15 58	60 62	3000 gm.	30 10	
2 7199	1410 94	30 55	120 22	6 5328	60 4872	
		1 47		10 25	120 28	
		2 37				

UNIVERSITY of ALBERTA DEPT. of CIVIL ENGINEERING SOIL MECHANICS LABORATORY CONSOLIDATION RESULTS	
PROJECT	Sugar Beet Molasses
SITE	
SAMPLE	
LOCATION	
HOLE	DEPTH
TECHNICIAN	DATE

Specific Gravity of Soil Solids G_s = 2.58 Height of Soil Solids H_s = 0.501 ins.

Void Ratio e (End) = 0.436

Void Ratio e(Start) = 0.898

Void Ratio e (Start Dimensions) = 0.796

e(End) = W%(End) x G_s $H_s = \left(\frac{\text{Wt. Soil}}{G_s \times \text{Area} \times 2.54}\right)$ ins. e = previous e $\pm \frac{\text{Def'l.}}{H_s}$

Time Interval	Load on Pan (gms)	Corr. Dial Reading (ins.)	Deflection (ins.)	$\frac{\text{Deflection}}{H_s}$	Void Ratio e	Pressure Kg/cm² = T/ft²
	0	6978			0.898	
	20	7272	+ .0294	.0587	0.957	0.070
	50	7152	.0120	.0239	0.9[illegible]3	0.158
	100	6835	.0317	.0633	0.870	0.304
	200	6538	.0297	.0593	0.811	0.596
	400	6160	.0378	.0755	0.755	1.18
	800	5721	.0439	.0877	0.647	2.34
	1500	5342	.0379	.0756	0.572	4.39
	3000	4990	.0352	.0703	0.502	8.77
	6000	4662	.0328	.0655	0.4[illegible]	17.5

Compressive Index = ______

Swelling Pressure = ______ T/ft²

Pre-Cons. Load = ______ T/ft²

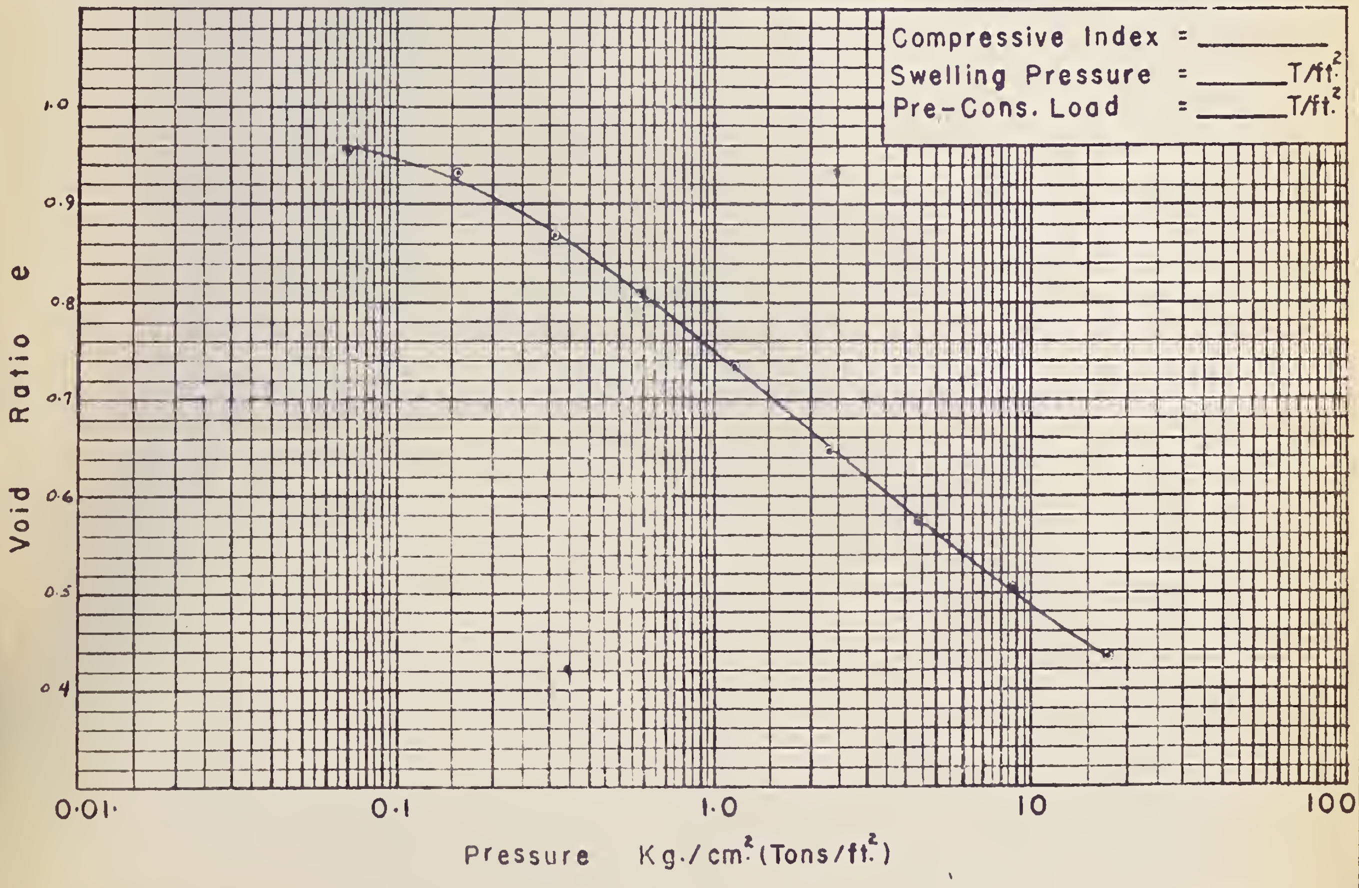


TABLE XXXIX

UNIVERSITY of ALBERTA
DEP'T of CIVIL ENGINEERING
SOIL MECHANICS LABORATORY

CONSOLIDATION DATA

PROJECT	Calgon
SITE	Solution Strength = 16.5 %
SAMPLE	Viscosity = 1.60 cs.k. (Room)
LOCATION	
HOLE	DEPTH
TECHNICIAN	DATE

Ring Data

Ring No. B11
Weight gm's. 596.57
Thickness ins. 0.9
Diameter ins.
Area sq cm's 34.2

Machine Data

Machine No. 2
Multiplication Factor 100
Wt. Block + Stone + Ball gm's.

Consolidation Sample Weights

Wt. Tare + Ring + Soil + Water (End) gms. 769.85
Wt. Tare + Ring + Soil (End) gms. 748.43
Wt. Tare (Tare No. T11) gms. 36.68
Wt. Ring + Soil + Water (End) gms. 733.17
Wt. Ring + Soil + Water (Start) gms. 746.78
Wt. Ring + Soil gms. 711.75
Wt. Soil gms. 115.18
Water (End) = 21.42 gms. = 18.6 %
Water (Start) = 35.03 gms = 30.4 %

Description of Sample: Initial Wet Density = 120.0 #/ft.³
Initial Dry Density = 91.7 #/ft.³

Date, Time Load, Dial Remarks	Date, Time Load, Dial Remarks	Date, Time Load, Dial Remarks	Date, Time Load, Dial Remarks	Date, Time Load, Dial Remarks	Date, Time Load, Dial Remarks	Date, Time Load, Dial Remarks
DEC. 10	23 9374	DEC. 17	30 8812	15 8432	125 8017	3050 7495
11:37	48 72	07:04	1 01	[illegible] 19	260 7968	4330 7490
20gm	105 71	400gm	2 8784	55 8398	360 45	
0 9262	150 71	3 9072	4 72	120 67	450 27	
3 58	240 71	6 65	8 62	170 48	1475 7068	
6 57	340 71	10 61	15 56	250 22	1915 58	
10 56	DEC. 15	15 58	30 47	345 02	2930 46	
15 45	09:24	30 40	60 2	460 8283	4800 32	
30 38	200gm.	1 42	120 8708	1445 29	5790 7032	
1 28	6 9265	2 33	210 8676	1890 25	JAN 2	
2 23	10 61	8 21	300 57	2880 10	09:34	
WATER	15 60	15 13	420 34	4400 8200	6000gm	
4 9323	30 58	30 9003	1440 8568	7200 8191	6 7812	
8 21	1 52	70 8985	1020 63	10,000 8187	10 10	
15 21	2 54	120 72	3000 47	DEC. 29	15 06	
140 25	4 52	240 50	4300 8538	08:57	30 05	
250 43	8 47	375 30	DEC. 22	3000gm	1 02	
1240 9332	12 43	430 23	08:47	6 8150	2 7798	
DEC. 11	26 33	1440 8885	1600gm	10 40	4 90	
08:52	60 22	1640 78	3 8498	15 42	8 78	
50gm.	125 05	2880 72	6 95	30 [illegible]	15 67	
5 9390	215 9180	DEC. 19	10 91	1 32	30 47	
10 85	290 65	07:06	15 85	2 25	50 23	
15 83	430 58	800gm.	30 78	4 20	120 32	
30 81	1410 25	3 8822	1 72	8 06	250 24	
1 80	1800 18	6 19	2 62	15 8094	330 7600	
2 79	3200 9115	10 16	4 56	30 76	410 7584	
5 78		15 14	8 45	60 52	1440 21	
14 75						

UNIVERSITY of ALBERTA
DEPT. of CIVIL ENGINEERING
SOIL MECHANICS LABORATORY

CONSOLIDATION RESULTS

PROJECT CALGON	
SITE Solution Strength = 16.5%	
SAMPLE Viscosity = 1.60 cstk. (Room)	
LOCATION	
HOLE	DEPTH
TECHNICIAN	DATE

Specific Gravity of Soil Solids G_s = 2.58 Height of Soil Solids H_s = 0.514 ins.

Void Ratio e (End) = 0.48

Void Ratio e (Start) = 0.845

Void Ratio e (Start Dimensions) = 0.732

e (End) = W% (End) x G_s $H_s = \left(\frac{\text{Wt. Soil}}{G_s \times \text{Area} \times 2.54}\right)$ ins. e = previous e $\pm \frac{\text{Def'l.}}{H_s}$

Time Interval	Load on Pan (gms)	Corr. Dial Reading (ins.)	Deflection (ins.)	Deflection / H_s	Void Ratio e	Pressure $Kg/cm^2 = T/ft^2$
	0	.9362			0.845	
	20	.9392	0.0030	0.0058	0.851	0.070
	0	.9371	.0021	.0041	0.846	[illegible]
	100	.9297	.0074	.0144	0.832	[illegible]
	200	.9115	.0182	.0354	0.797	[illegible]
	400	.8872	.0243	.0474	0.749	1.18
	800	.8538	.0334	.0651	0.684	2.34
	1200	.8187	.0321	.0653	0.616	4.39
	3000	.7832	.0325	.0632	0.547	8.77
	6000	.7490	.0342	.0666	0.4[illegible]	11.[illegible]